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PRESIDENT OF THE INSTITUTION OF MINING ENGINEERS, 1893-94.

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OF

THE INSTITUTION

OF

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WILLIAMS, ROBERT, 30, Clement's Lane, Lombard Street, London, E.C.
WILLIAMS, SAMUEL HERBERT, 23, Somerset Avenne, Winthrop, Massachusetts, U.S.A.
WILLIAMSON, J., The Hills, Cannock, Staffordshire.
WILLIAMSON, J. H., Henshall House, Goldenhill, Stoke-upon-Trent.
WILLIAMSON, R., The Denaby and Cadeby Main Colliery Offices, Conisborough, near Rotherham.
WILLIAMSON, R. S., Cannock Wood House, Hednesford, Staffordshire.
WILLIAMSON, THOMAS, West Hallam Collieries, Ilkeston.
WILLIAMSON, WILLIAM, Opal Cottage, Burnblea, Hamilton, N.B.
WILLIS, EDWARD T., Hockley Hall Collieries, Tamworth.
WILSON, ARCHIBALD LAWRENCE, The New Ravenswood, Limited, Ravenswood, Queensland, Australia.
WILSON, ARTHUR P., Mansion House Chambers, Queen Victoria Street, London, E.C.
WILSON, BENJAMIN.
WILSON, DAVID, Wester Gartshore Colliery, Kirkintilloch.
WILSON, GEORGE, Blairadam Colliery, Kelty, Fifeshire.
WILSON, JOHN, 397, Harewood Street, Bradford.
WILSON, JOHN, Neilston Colliery, Kilsyth, N.B.
WILSON, JOHN, 75, Bothwell Street, Glasgow.
WILSON, JAMES R., Preston Links, Prestonpans, N.B.
WILSON, JOSEPH R., 941, St. Bernard Street, Philadelphia, Pennsylvania, U.S.A.
WILSON, JOHN R. ROBINSON, H.M. Inspector of Mines, West Hill, Chapeltown Road, Leeds.
WILSON, LLOYD, Flimby Colliery, Maryport.
WILSON, NATHANIEL, Colonial Assurance Chambers, 30, St. George's Street, Cape Town, South Africa.
WILSON, P. O.
WILSON, ROBERT, Bathville Collieries, Armadale, N.B.
WILSON, W. B., Hawthorn Rectory, Sunderland.
WILSON, WILLIAM BRUMWELL, Jun., Wheatley Hill Colliery, Thornley, R.S.O., Co. Durham.
WILSON, W. E. C., West Cannock Colliery Company, Hednesford, Staffordshire.
WILSON-MOORE, AUBREY PERCY, Poste Restante, Durban, Natal, South Africa.
WILSON-MOORE, CUNINGHAME, Poste Restante, Durban, Natal, South Africa.
WINCHELL, HORACE V., Butte, Montana, U.S.A.
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WINSTANLEY, PETER, Shaw Cross Colliery, near Dewsbury.
WINSTANLEY, ROBERT, 42, Deansgate, Manchester.
WITHERS, CHARLES, 65, Station Street, Nottingham.
WITTY, H. SYKES, Denaby Main House, near Rotherham.
WOLSTENHOLME, M., Llanfoist House, near Abergavenny.
WOOD, C. L., Freeland, Forgandenny, Perthshire.
WOOD, E. S., c/o Bengal Coal Company, Limited, 5, Fairlie Place, Calcutta, India.
WOOD, JAMES, 28, Royal Exchange Square, Glasgow.
WOOD, JOHN, Coxhoe Hall, Coxhoe, R.S.O., Co. Durham.
WOOD, JNO., Barley Brook Foundry, Wigan.
WOOD, Sir LINDSAY, Bart., The Hermitage, Chester-le-Street.
WOOD, ROBERT ARNA, c/o Harrison, Barber and Company, Limited, 18, Queen Victoria Street, London, E.C.
WOOD, THOMAS, North Hetton Colliery Office, Moorsley, Hetton-le-Hole, R.S.O.
WOOD, W. H., Coxhoe Hall, Coxhoe, R.S.O., Co. Durham.
WOOD, WALTER K., 54, Kyle Park, Uddingston, N.B.
WOOD, W. O., South Hetton, Sunderland.
*WOODALL, WILLIAM, Bleak House, Burslem, Stoke-upon-Trent.
WOODBURN, J. ALLAN, Rezende, Limited, Penhalonga, Umtali, Rhodesia, British South Africa.

WOODBURNE, T. J., Bultfontein Mine, De Beers Consolidated Mines, Limited, Kimberley, South Africa.
WOODHEAD, ALFRED, Low Moor Iron Works, Bradford.
WOODHEAD, L., Beeston Colliery, Leeds.
WOODS, RICHARD, Seymour Colliery, Staveley, Chesterfield.
WOODWORTH, BENJAMIN, Heron Cross, Fenton, Stoke-upon-Trent.
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WORDSWORTH, ROBERT, Warora Colliery, Central Provinces, India.
WORDSWORTH, T. H., New Moss Colliery, Audenshaw, near Manchester.
WORMALD, C. F., Mayfield Villa, Saltwell, Gateshead-upon-Tyne.
WORSDELL, WILSON, North Eastern Railway, Gateshead-upon-Tyne.
WRIGHT, HENRY, Market Street, Ilkeston, near Nottingham.
WRIGHT, JOSEPH, Arboretum Street, Nottingham.
WRIGHT, SIDNEY BRISTOW, Canadian Goldfields, Limited, Deloro, Ontario, Canada.
WRIGHTSON, Sir THOMAS, Bart., Stockton-upon-Tees.
WROE, JAMES, Croft House, Featherstone, Pontefract.
WROE, JONATHAN, Wharncliffe Silkstone Colliery, Barnsley.
WYNNE, THOMAS TRAFFORD, c/o W. Watkyn Wynne, Station Road, Stone, Staffordshire.
WYPER, JAMES, Townlands Colliery, Hamilton, N.B.
WYSEHALL, GEORGE E., 53, Shirland Lane, Attercliffe, Sheffield.

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YOUNG, HENRY WILLIAM, Greymouth, New Zealand.
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YOUNG, JOHN, Baljaffray Colliery, Bearsden, Glasgow.
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YOUNG, J. HUNTLEY, Wearmouth Colliery, Sunderland.
YOUNG, ROBERT, Tacoma, Washington, U.S.A.

ZUMBULOGLON, G. C., Mahmoudie-Han, Stamboul, Turkey.

Associate Members.

Assoc.M.Inst.M.E.

Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.

* Deceased.

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BATT, THOMAS, Beech Grove, Oulton, Leeds.
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CHEWINGS, CHARLES, Albany, Western Australia.
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COOPER, R. W., Newcastle-upon-Tyne.
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COX, PERCY MOTTRAM, Stoke-upon-Trent.
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LORENZ, DR. THEODOR, Samarinda, East Coast, Dutch Borneo.
LOWES, WILLIAM, Ballarat and Prince Oscar Gold Mines, Kanowna, Western Australia.
LUMSDEN, JOHN ALDER, Rewah State Collieries, Umaria, C.P., India.

MACDONALD, COLIN OCHILTREE, Gowrie and Black House Collieries, Limited, Port Morien, Cape Breton, Nova Scotia, Canada.
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MALSON, W. A., Sheffield Road, Chesterfield.
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PAVITT, HAROLD HASTINGS, Greymouth, New Zealand.
PERKINS, CHARLES, Middleton Hall, Belford, Northumberland.
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PRINGLE, JOHN, c/o Russo-Chinese Bank, Newchwang, China.
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SCOTT, JOHN HENRY, 1157, Burnaby Street, Vancouver, British Columbia.
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SMITH, CLARENCE D., Guildhall, Newcastle-upon-Tyne.
SNOWBALL, FRANCIS JOHN, Seaton Burn House, Dudley, Northumberland.
STANDRING, P. W. D., Strafford Collieries, Barnsley.
STEELE, H. B., Hanley Borough Colliery, Hanley, Staffordshire.
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STEWART, SAMUEL, 16, Great George Street, Westminster, London, S.W.
STOKES, H. G., Silver Spur Silver Mine, Texas, *via* Stanthorpe, Queensland, Australia.
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STRANGE, HAROLD FAIRBROTHER, P. O. Box 590, Johannesburg, Transvaal.
STREET, G. P,, Knutton Mining Manor Company, Silverdale, Staffordshire.
SWINBURNE, U. P., Copheaton, Newcastle-upon-Tyne. *Transactions* to be sent to The Tati Concessions, Limited, Francistown, Tatai, Matabeleland, South Africa.

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TODD, JAMES, West View House, Durham.
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TURNER, CHARLES EDWARD, Kohikohi Company, Murchison, *via* Nelson, New Zealand.

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WILLIAMS, THOMAS J., Colebrook Copper Mine, Orrville, Tasmania.
WILSON, ANTHONY, Thornthwaite, Keswick, Cumberland.
WOOD, ARTHUR NICHOLAS LINDSAY, The Hermitage, Chester-le-Street.
WRIGHTSON, WILFRID INGRAM, Neasham Hall, Darlington.

YATES, FREDERICK BLAKELEY, 2, Mount Street, Manchester.

Associates.

Assoc.Inst.M.E.

Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.

* Deceased.

ADAMS, CHARLES, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
ALLPORT, E. A., 89, Dodworth Road, Barnsley, Yorkshire.
ARCHER, M. W., High Priestfield, Lintz Green, Co. Durham.

BALL, JOSEPH, Fish Pond Farm, near Mansfield.
BARBER, JOSEPH, Ansley Hall Collieries, Atherstone.
BARKER, JOHN DUNN, 23, Cobden Terrace, Brandon Colliery, R.S.O., Co. Durham.
BATES, WILLIAM, Birley East Collieries, Sheffield.
BATTEY, THOMAS, Percy Terrace, Backworth Colliery.
BAYLDON, HAROLD CRESSWELL, c/o Bechuanaland Exploration Company, Limited, Bulawayo, Rhodesia, South Africa.
BECKETT, JAMES, 16, Church Street, Dunston-upon-Tyne.
BEDFORD, A., East Bierley, near Bradford.
BELL, JOHN, Wardley Colliery, Newcastle-upon-Tyne.
BELL, THOMAS, White Lea Colliery, Crook, R.S.O., Co. Durham.
BELL, W. R., Wearmouth Colliery, Sunderland.
BENTLEY, GEORGE, Bradford Colliery, Manchester.
BEWICK, GEORGE, 44, Thomas Street, Coundon Grange, Bishop Auckland.
BEXTON, R., West Hill Terrace, Skegby, Mansfield.
BLACKBURN, HOWARD, Hygienic Villas, Woodhouse, Sheffield.
BLAIKIE, JOHN, Bridge House, Newcastle, Staffordshire.
BOOTH, AARON, Hilcote, Blackwell, Alfreton.
BOOTH, FRED. L., Ashington Colliery, Morpeth.
BOWES, THOMAS, Pontop House, Annfield Plain, R.S.O.
BOWMAN, FRANK, Ouston Colliery Office, Chester-le-Street, Co. Durham.
BRAMLEY, WILLIAM, Bagot Villa, West Hallam, Derby.
BROMLEY, OLIVER J., Leycett, near Newcastle, Staffordshire.
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CALLAND, ROBERT, East Hedley Hope Colliery, Tow Law, R.S.O., Co. Durham.
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CLARE, HENRY, Birchenwood Colliery Company, Limited, Kidsgrove, Stoke-upon-Trent.
CLARK, THOMAS, Dipton Colliery, Lintz Green Station, Co. Durham.
CLOUGH, JOHN, 1, Melton Terrace, Seaton Delaval, R.S.O., Northumberland.
COCKBURN, EVAN, Page Bank Colliery, *via* Spennymoor, Durham.
COLLIS, G. E., Chapel Road, Grassmoor, Chesterfield.
CORBETT, VINCENT, 2, Grey Terrace, Ryhope, *via* Sunderland.
COWX, H. F., Thornley Collieries, *via* Trimdon Grange, R.S.O.
CUTTS, GEORGE, Digby Road, Kimberley, Nottinghamshire.

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DANSKIN, THOMAS, Springwell Colliery, Gateshead-upon-Tyne.
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DAY, SAMUEL, Ashtree Villas, Grassmoor, Chesterfield.
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ELLIOTT, DANIEL, Houghton Main Colliery, Barnsley.
ELLIOTT, J. W., Kirkby Colliery, Kirkby-in-Ashfield, Nottingham.
ELTRINGHAM, GEORGE, Eltringham Colliery, Prudhoe-upon-Tyne, R.S.O.
ELVES, EDWARD, Middridge Colliery, Heighington, R.S.O.
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FOX, JOHN, Norton Cannes, Cannock, Staffordshire.

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2.—The object of the Benevolent Fund is to afford assistance to necessitous Members, Associate Members, Associates and Students of The Institution of Mining Engineers and their families.

3.—The Fund shall be supported by means of Annual Subscriptions, Donations and Bequests.

4.—Contributors to the Fund shall be entitled to vote at all General and Extraordinary General Meetings.

5.—The affairs of the Fund shall be conducted by the "Committee of Management," consisting of seven members, and composed as follows :—The President, for the time being, of The Institution of Mining Engineers, and six Contributors to the Fund.

6.—The Committee of Management shall have full power to make grants and afford assistance to any necessitous Member, Associate Member, Associate or Student of The Institution of Mining Engineers, or to their families.

7.—The names of the applicants for, and the recipients of, the assistance afforded by the Fund, shall not necessarily be published.

8.—The fact of having been a Contributor to the Fund shall not in any case constitute a claim to participate in it.

9.—The Committee of Management shall not make any grants or payments by which the donations, bequests, or income of future years shall be anticipated, or appropiated.

Members are desired to send subscriptions or donations to Mr. M. Walton Brown, Neville Hall, Newcastle-upon-Tyne.

400

TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
AUGUST 4TH, 1900.

MR. WILLIAM ARMSTRONG, RETIRING-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings on July 21st and that day, and of the Council of The Institution of Mining Engineers.

ELECTION OF OFFICERS, 1900-1901.

The CHAIRMAN (Mr. W. Armstrong) appointed Messrs. R. Clive, J. W. Fryar, C. C. Leach, N. B. Ridley, F. R. Simpson, and J. Simpson as scrutineers of the balloting papers for the election of officers for the year 1900-1. The scrutineers afterwards reported the result of the ballot as follows:—

PRESIDENT:
Mr. J. G. WEEKS.

VICE-PRESIDENTS:

Mr. T. W. BENSON.	Mr. J. H. MERIVALE.
Mr. T. FORSTER BROWN.	Mr. M. W. PARRINGTON.
Mr. J. L. HEDLEY.	Mr. W. O. WOOD.

COUNCIL:

Mr. R. S. ANDERSON.	Mr. A. C. KAYLL.
Mr. H. AYTON.	Mr. P. KIRKUP.
Mr. R. DONALD BAIN.	Mr. H. LAWRENCE.
Mr. G. F. BELL.	Mr. C. C. LEACH.
Mr. W. C. BLACKETT.	Prof. HENRY LOUIS.
Mr. H. F. BULMAN.	Mr. R. A. S. REDMAYNE.
Mr. M. H. DOUGLAS.	Mr. T. O. ROBSON.
Mr. T. E. FORSTER.	Mr. F. R. SIMPSON.
Mr. T. E. JOBLING.	Mr. J. SIMPSON.

Mr. W. ARMSTRONG (Retiring-President), in vacating the chair in favour of Mr. J. G. Weeks, said that the members had every reason to congratulate themselves in having elected so able a President for the ensuing year.

The PRESIDENT (Mr. J. G. Weeks) thanked the members for the great honour which they had done him in electing him as President. He assured the members that his care would be to further, so far as lay in his power, the interests of the Institute. Towards this end he was much emboldened by the thought that he could rely upon a continuance of that help and support which had always so considerately and generously been given, not only by the members generally, but also by the Council, to his predecessors. Although a steady increase of membership was desirable, it was not necessarily a measure of success appertaining to a scientific institute; and, while desiring the assistance of the members in this respect during his term of office, he wished more particularly to emphasize the opinion that the production of papers (with the attendant discussion) dealing with either safety in, or the beneficial progress of, the art of mining (which he begged to remind them were the principal objects placed prominently in front at the foundation of the Institute in 1852), was one of greater importance, stimulated as he hoped it would be by Mr. G. C. Greenwell's donation, alluded to in the annual report, and one in which their co-operation was earnestly requested.

Before resuming his seat, he had an immediate duty to perform, namely, to move a vote of thanks to the retiring-President. They had seen the very genial and hearty way in which he had so successfully filled the position of President; he had been a brilliant illustration of heredity in mining talent, and which would be, he hoped, associated with the name of Armstrong for many future generations. His most excellent address (like Sir Walter

Scott's novels) would bear reading over any number of times, and was as appropriate now as on the day upon which it was delivered; and taken in conjunction with those of his predecessors in the chair, the ground had been so completely covered that he (Mr. Weeks) might be well excused if he did not attempt one.

Mr. GEORGE MAY (Past-President) seconded the vote of thanks to the retiring-President, which was very cordially adopted.

Mr. W. ARMSTRONG, having briefly replied, moved that the thanks of the members be given to the Vice-Presidents, members of Council, and the Secretary and Treasurer, for their services during the past year.

Mr. R. S. ANDERSON seconded the motion, which was heartily adopted.

Mr. W. C. BLACKETT moved, and Mr. W. ARMSTRONG seconded a vote of thanks to the scrutineers for their services, and it was cordially approved.

The Annual Report of the Council was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1899-1900.

The following table shows the progress of the membership during the last three years:—

Year ending August 1st.	1898.	1899.	1900.
Honorary Members...	30	29	30
Members	859	870	883
Associate Members	115	126	132
Associates	103	109	108
Students	51	62	59
Subscribers	22	23	23
Totals	1,180	1,219	1,235

The continuing increase of the membership is a matter of congratulation. 110 members of all classes have been added to the register during the past year, and after allowing for losses by deaths and resignations, there is a net increase of 16 members.

The deaths include Messrs. T. W. Asquith (who had served on the Council), Samuel Bailey, Thomas Brown, Joseph Chater, E. S

Clark, H. D. Cowan, E. W. Crone, J. Douglas, R. Elsdon, J. W. Foster, H. Henderson, J. Hodgson, J. G. Joicey, G. F. Labram (killed during the siege of Kimberley), R. Nasse, S. Oliver, J. M. Rogers, L. I. Seymour (killed in an engagement at Zand River), W. Smyth and I. W. H. White.

The Library has been maintained in an efficient condition during the year. The additions by donation, exchange and purchase, have been:—

Bound volumes	390
Pamphlets, reports, etc.	299
A total of	689 titles.

And the Library now contains about 8,389 volumes, and 2,299 unbound pamphlets.

The sets of some of the files of publications are incomplete, owing to the loss of volumes or parts, and it is urgently desired that members will return the missing volumes, etc., to the librarian. The Council have been reluctantly compelled to decide that unbound publications shall be withdrawn from circulation.

Members would render useful service to the profession by presentations of books, reports, and plans to the Library, where they would be available for reference.

By arrangement with the Literary and Philosophical Society of Newcastle-upon-Tyne, the members of either Institution are permitted to refer to the books in the Library of the other society. The members are also permitted to enter the Museum of the Natural History Society, in Newcastle-upon-Tyne.

The Library contains the complete publications (maps, memoirs, etc.) of the Geological Survey of the United Kingdom. They are available for reference by members, but may not be removed.

The Durham College of Science, at the suggestion of the Council, has arranged a three years' course of lectures for colliery-engineers, enginewrights, and apprentice mechanics, commencing in October in each year. The lectures are delivered on Saturday afternoons, and the course is as follows:—

1900-1. Michaelmas Term, (1) Mensuration, and (2) Chemistry of Fuel. Epiphany Term, (3) Strength of Materials, and (4) Experimental Mechanics.

1901-2. Michaelmas Term, (5) Theoretical Electricity, and

(6) Haulage and Winding. Epiphany Term, (7) Steam-engines and Boilers, and (8) Electrical Engineering.

1902-3. Michaelmas Term, (9) Metallurgy of Iron and Steel, and (10) Pumping and Ventilation. Epiphany Term, (11) Transmission of Power, and (12) Mining Machinery (chiefly used underground.

Several colliery-owners have paid the fees (30s. per annum) and railway-expenses of pupils attending the classes from their respective collieries. During the past year, the lectures during the Michaelmas Term were attended by 89 students, 52 sat for examination, and 28 passed; and during Epiphany term there were 74 students, 49 were examined, and 30 passed.

The adoption of a composition, varying with age, payable in lieu of future subscriptions, has been generally approved, as evidenced by the number of members who have compounded. The scale of rates is:—Under 30 years of age, £31; over 30 years, £27; over 40 years, £24; over 50 years, £21; and over 60 years £17.

The *Report of the Committee of the North of England Institute of Mining and Mechanical Engineers, and the Midland Institute of Mining, Civil and Mechanical Engineers on Mechanical Ventilators* has been published by The Institution of Mining Engineers. The thanks of the Institute were due to the members of the Committee for the interesting and valuable report which has been drafted by their honorary secretary.

An Account of the Strata of Northumberland and Durham as proved by Borings and Sinkings has been published in six volumes. Members are desired to send copies of any unpublished sections of strata in these counties, or their section books on loan, in order that they may be published in a supplementary volume.

The prices of the *Transactions* (vols. i. to xxxviii.) have been considerably reduced, and members are desired to complete their sets before the stock is exhausted (vols. iii., iv., v., vi. and xxi. are now out of print).

Arrangements have been made for the holding of meetings for the reading of papers and discussions by the junior members, and the Council trust that the associates and students will attend and ensure their success.

Mr. M. Walton Brown has been appointed to represent the Institute at the conference of corresponding societies of the British

Association for the Advancement of Science to be held at Bradford in September, 1900. Messrs. M. Walton Brown, C. C. Leach, H. Louis and John Vivian attended, as delegates, at the receptions of the Société des Ingénieurs Civils de France in connexion with the Paris Exhibition from June 15th to 20th, 1900. Messrs. Alexander Agassiz and R. P. Rothwell represented the Institute at the commemoration exercises held in October, 1899, to celebrate the hundreth anniversary of the foundation of the Connecticut Academy of Arts and Sciences. Mr. John Daglish represents the Institute on the Council of the Durham College of Science. Mr. W. Cochrane is the representative of the Institute on the Science and Art Committee, and Mr. Henry Ayton on the Scholarships Committee of the Northumberland County Council. Mr. W. Cochrane also represents the Institute on the board of directors of The Institute and Coal Trade Chambers Company, Limited.

Prof. H. Louis gave evidence on behalf of the Institute before the Department Committee upon the work of the Geological Survey of the United Kingdom.

The representatives of this Institute on the Council of the Institution of Mining Engineers during the past year were as follows:—Messrs. Henry Armstrong, William Armstrong, J. Batey, W. C. Blackett, Bennett, H. Brough, T. Forster Brown, A. G. Charleton, William Cochrane, Benjamin Dodd, G. B. Forster, T. E. Forster, John Gerrard, Reginald Guthrie, John L. Hedley, T. E. Jobling, A. C. Kayll, C. C. Leach, Henry Louis, John Morison, Henry Palmer, T. O. Robson, F. R. Simpson, A. L. Steavenson and J. G. Weeks.

Mr. G. C. Greenwell, one of the original members, a past-president and an honorary member, in order to further promote the original object for which the Institute was founded, namely "for the purpose of forming a society to meet at fixed periods and discuss the means for the ventilation of coal-mines, for the prevention of accidents, and for general purposes connected with the winning and working of collieries," has offered a donation of £100 to provide for the annual award of gold, silver and bronze medals for papers recording the results of experience, and the deductions and practical suggestions of the writers, for the avoidance of accidents.

The following additional exchanges have been arranged during the year:—

Bulletin Russe de Statistique Financière et de Législation.
Geological Survey of the Colony of Natal.
The University Geological Survey of Kansas.

The Council are of opinion that the experience of the past has proved the desirability of forming a Benevolent Fund in connexion with the Institute, similar to the Benevolent Fund of the Institution of Civil Engineers, established in 1864, when the membership of that Institution was much less (1,040) than the present membership (1,235) of the Institute. There is no doubt that a well-managed and adequately-supported Benevolent Fund would prove advantageous to members who may be overtaken by misfortune. The question of the promotion of a general fund is being considered by The Institution of Mining Engineers.

Prizes of books have been awarded to the writers of the following papers communicated to the members during the year 1898-99:—

"The Western Interior Coal-field of America." By Mr. H. Foster Bain.
"Transvaal Coal-field." By Mr. William Peile.
"The Ore-deposits of the Silver Spur Mine and Neighbourhood, Texas, Queensland." By Mr. H. G. Stokes.

The papers contributed during the year are as follow:—

"The Driving of a Stone-drift at the West Wylam Collieries." By Mr. Sidney Bates.
"The Kalgoorlie Gold-field." By Mr. S. J. Becher.
"Description of Present and Proposed Methods of Operating Vinton No. 3 Colliery, Vintondale, Pennsylvania, U.S.A." By Mr. Clarence R. Claghorn.
"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse.
"Automatic Sprayer for Preventing Accumulations of Dust in Mines." By Mr. R. Harle.
"The Coal-fields of Natal." By Mr. Wm. Taylor Heslop.
"The Composition of Certain British Coals." By Prof. Henry Louis.
"Ore-deposits of Mount Lyell, Tasmania." By Mr. J. J. Muir.
"The Mineral Resources of Tasmania." By Mr. John J. Sandeman.

The connexion with The Institution of Mining Engineers has now existed for eleven years. During the past year, meetings have been held at Sheffield in September, 1899, in London in June, 1900, and in Paris, in connexion with the International Congress of Mining and Metallurgy, in June, 1900. The members may be congratulated upon the number and varied nature of the papers printed in the *Transactions*, and the Council trust that similar contributions will be forwarded as liberally in the future.

In conclusion, the Council desire to impress upon the members that the success of the Institute in the future is dependent upon an increase in the membership, so as to meet the increased expenses incurred by its connexion with The Institute of Mining Engineers.

Mr. W. ARMSTRONG moved the adoption of the report.

Mr. W. C. BLACKETT seconded the resolution, which was unanimously agreed to.

The SECRETARY read the Report of the Finance Committee as follows:—

REPORT OF THE FINANCE COMMITTEE.

The Finance Committee submit herewith a statement of accounts for the twelve months ending June 30th, 1900.

The total receipts during that period were £2,687 14s. 7d. Of this amount, £127 was paid as life-compositions in lieu of annual subscriptions, and £74 2s. represented subscriptions paid in advance, leaving £2,486 12s. 7d. as the ordinary income of the year, as compared with £2,579 4s. 2d. in the previous year. The decrease is caused by the fact that in the previous year one and a half year's interest on the mortgage of the Institute and Coal Trade Chambers Company, Limited, was included, and in that year also interest was received from the bankers on sums deposited with them, which have since been withdrawn for the purpose of payment of the cost of alterations to the Wood Memorial Hall.

The ordinary expenditure amounted to £2,069 12s. 7d., leaving a balance of ordinary receipts over ordinary expenditure of £417. There was also paid the balance of the cost of alterations to the Wood Memorial Hall, £378 1s., making the total payments for the year £2,447 13s. 7d.

During the year, £421 15s. has been written off the amount of subscriptions and arrears. This large sum is due to the Council having removed from the list all members who had failed to respond to numerous applications for subscriptions and arrears. The collection of the amounts due in many cases has been placed in the hands of the solicitors, and a portion will subsequently be recovered and credited to the year in which the sums are

received. It is to be regretted that, even after the amount has been struck off as shown above, there is still a very considerable sum in arrear, the amount of subscriptions for the year 1899-1900 yet unpaid being £286 10s., and for previous years £60 18s. The Committee would impress upon the members the necessity for the payment of subscriptions at the time when they become due, in order to avoid the considerable inconvenience and loss which are otherwise caused.

JOHN G. WEEKS.

July 21st, 1900.

Mr. W. ARMSTRONG moved the adoption of the report.

Mr. W. C. BLACKETT seconded the resolution, which was agreed to.

Mr. W. ARMSTRONG directed the attention of the members to the donation from Mr. G. C. Greenwell, and he moved that a hearty vote of thanks be accorded to that gentleman for his generous offer to provide gold, silver and bronze medals as awards for papers.

Mr. J. L. HEDLEY (H. M. Inspector of Mines) said that as a former assistant to Mr. Greenwell he had great pleasure in seconding the vote of thanks. He had known Mr. Greenwell for many years and had the honour and pleasure of being partly trained by him, and with his acquired experience he could not too highly express his appreciation of the way in which Mr. Greenwell conducted the work at the collieries under his charge.

The vote of thanks was cordially approved.

DR. THE TREASURER IN ACCOUNT WITH THE NORTH OF ENGLAND FOR THE YEAR ENDING

June 30th, 1899.	£	s.	d.	£	s.	d.
To Balance at Bankers	527	18	9			
„ „ in Treasurer's hands	47	0	8			
„ Outstanding Amount due for Authors' Excerpts ...	0	4	4			
June 30th, 1900.				575	3	9
To Dividend of 7½ per cent. on 146 Shares of £20 each in the Institute and Coal Trade Chambers Company, Limited, for year ending June 30th, 1900	219	0	0			
„ Interest on Mortgage of £1,400 with the Institute and Coal Trade Chambers Company, Limited.	49	0	0			
				268	0	0
„ Sale of *Transactions*				31	18	7
To SUBSCRIPTIONS FOR 1899-1900 AS FOLLOWS:—						
677 Members ... ... @ £2 2s.	1,421	14	0			
85 Associate Members ... ... @ £2 2s.	178	10	0			
90 Associates ... ... @ £1 5s.	112	10	0			
53 Students ... ... @ £1 5s.	66	5	0			
69 New Members ... . @ £2 2s.	144	18	0			
15 New Members (not yet elected) ... @ £2 2s.	31	10	0			
21 New Associate Members ... ... @ £2 2s.	44	2	0			
6 New Associates ... . @ £1 5s.	7	10	0			
1 New Associate (on account)	1	1	0			
10 New Students ... . @ £1 5s	12	10	0			
	2,020	10	0			
23 Subscribing Firms	96	12	0			
	2,117	2	0			
To LIFE COMPOSITIONS:—						
3 New Members £72 0 0						
1 New Member (not yet elected) ... 24 0 0						
1 New Student 31 0 0						
	127	0	0			
	2,244	2	0			
Less—Subscriptions for current year paid in advance at the end of last year...	86	2	0			
	2,158	0	0			
Add—Arrears received	155	14	0			
	2,313	14	0			
Add—Subscriptions paid in advance during the current year	74	2	0			
				2,387	16	0
				£3,262	18	4

INSTITUTE OF MINING AND MECHANICAL ENGINEERS. CR.
JUNE 30TH, 1900.

June 30th, 1900.	£	s.	d.	£	s.	d.
By Circulars, etc.	67	13	7			
„ Cleaning Offices	33	12	1			
„ Coals, Electric Light, Gas and Water	54	1	11			
„ Expenses of General Meetings	22	3	0			
„ Fire Insurance	13	7	9			
„ Furniture and Repairs	33	8	3			
„ Incidental Expenses	11	1	8			
„ Library—Binding £47 3 0						
„ „ Books 39 0 7						
	86	3	7			
„ Postages—Circulars 46 13 3						
„ „ Correspondence 9 18 9						
„ „ Reports 12 8 8						
	69	0	8			
„ Prizes for Papers	6	6	0			
„ Rates and Taxes	21	6	9			
„ Rent of Offices	22	1	10			
„ Reporting General Meetings	18	11	0			
„ Salaries, Wages, Auditing, etc.	380	16	9			
„ Stationery, etc.	29	5	10			
„ Telephone Rent, etc.	5	13	8			
„ Translations of Papers	2	14	0			
				877	8	4
By The Institution of Mining Engineers	1,192	12	0			
Less—Amounts paid by Authors for Excerpts ...	0	7	9			
				1,192	4	3
				2,069	12	7
By Wood Memorial Hall: Alterations				378	1	0
				2,447	13	7
By Balance at Bankers	753	3	2			
„ „ in Treasurer's hands	61	17	3			
„ Outstanding Amount for Authors' Excerpts	0	4	4			
				815	4	9
				£3,262	18	4

We have examined the above account with the books and vouchers relating thereto, and certify that, in our opinion, it is correct.

JOHN G. BENSON AND SON,
CHARTERED ACCOUNTANTS.

Newcastle-upon-Tyne,
August 4th, 1900.

DR. THE TREASURER IN ACCOUNT

		£	s.	d.	£	s.	d.
To 870 Members.							
45 of whom have paid Life Compositions.							
825	@ £2 2s.				1,732	10	0
To 126 Associate Members.							
8 of whom have paid Life Compositions.							
118	@ £2 2s.				247	16	0
To 109 Associates	@ £1 5s.				136	5	0
To 62 Students	@ £1 5s.				77	10	0
To 23 Subscribing Firms	... ...				96	12	0
To 69 New Members	@ £2 2s.				144	18	0
To 15 New Members, not yet elected...	... ...				31	10	0
To 3 New Members, paid Life Composition	... ...				72	0	0
To 1 New Member. not yet elected, paid Life Composition					24	0	0
To 21 New Associate Members @ £2 2s.	... ...				44	2	0
To 7 New Associates	@ £1 5s.				8	15	0
To 10 New Students	@ £1 5s.				12	10	0
To 1 New Student, paid Life Composition	... ...				31	0	0
					2,659	8	0
To Arrears, as per Balance Sheet 1898-99	... ...	£506	2	0			
Add—Fines	... ...	1	7	0			
Add—1 Member, paid for 1898-99	... .	2	2	0			
					509	11	0
					3,168	19	0
To Subscriptions Paid in Advance	.. ..				74	2	0
					£3,243	1	0

WITH SUBSCRIPTIONS, 1899-1900. CR.

			PAID. £ s. d.	UNPAID. £ s. d	STRUCK OFF LIST. £ s. d.
By 677	Members, paid	@ £2 2s.	1,421 14 0	.....	.....
By 106	„ unpaid ...	@ £2 2s.	.....	222 12 0	...
By 33	„ struck off list	@ £2 2s.	. ...	.....	69 6 0
By 9	„ dead	@ £2 2s.	.....	.....	18 18 0
825					
By 85	Associate Members, paid	@ £2 2s.	178 10 0	.....	.....
By 22	„ „ unpaid	@ £2 2s.	.....	46 4 0	.....
By 11	„ „ struck off list ...		... ..	... ..	23 2 0
118					
By 90	Associates, paid	@ £1 5s.	112 10 0	.....	.....
By 8	„ unpaid ...	@ £1 5s.	.....	10 0 0	.....
By 10	„ struck off list	@ £1 5s.	.....	.....	12 10 0
By 1	„ dead ...	@ £1 5s.	... ..	... ..	1 5 0
109					
By 53	Students, paid	@ £1 5s.	66 5 0	.....	.....
By 6	„ unpaid ...	@ £1 5s.	. ...	7 10 0	.....
By 2	„ struck off list	@ £1 5s.	.. ...	.....	2 10 0
By 1	„ dead	@ £1 5s.	.....	.....	1 5 0
62					
By 23	Subscribing Firms		96 12 0	.....	.....
By 69	New Members, paid ...	@ £2 2s.	144 18 0	.....	.....
By 15	New Members, not yet elected, paid...	@ £2 2s.	31 10 0	.....	.....
By 3	New Members, paid Life Composition...		72 0 0	.....	.....
By 1	New Member, not yet elected, paid Life Composition		24 0 0	.....	.....
By 21	New Associate Members, paid	@ £2 2s.	44 2 0	.....	.....
By 6	New Associates, paid ...	@ £1 5s.	7 10 0	.....	.....
By 1	New Associate, paid on account ...		1 1 0	0 4 0	.....
By 10	New Students, paid ...	@ £1 5s.	12 10 0	.....	.....
By 1	New Student, paid Life Composition ...		31 0 0	.....	.....
			2,244 2 0	286 10 0	128 16 0
By Arrears		£154 7 0	.....	60 18 0	292 19 0
Add—Fines		1 7 0	.. ...	.....	.....
			155 14 0		
			2,399 16 0		
By Subscriptions paid in advance			74 2 0	.. ...	.....
			2,473 18 0	347 8 0	421 15 0
					347 8 0
					2,473 18 0
					£3,243 1 0

General Statement, June 30th, 1900.

Liabilities.

	£	s.	d.	£	s.	d.
Subscriptions paid in advance	74	2	0			
Stationery	15	14	0			
The Institution of Mining Engineers ...	39	4	2			
				129	0	2
Capital				11,199	16	8
				£11,328	16	10

We have examined the above account with the books, vouchers and securities relating thereto, and certify that, in our opinion, it is correct. We have accepted the assets, books, pictures, etc., and *Transactions* and other Publications as valued by your Officials.

JOHN G. BENSON AND SON,
Chartered Accountants.

Newcastle-upon-Tyne,
August 4th, 1900.

Assets.

	£	s.	d.	£	s.	d.
Balance of Account at Bankers	753	3	2			
„ in Treasurer's hands	61	17	3			
Outstanding amount for Authors' Excerpts ...	0	4	4			
				815	4	9
Arrears of Subscriptions	.....			347	8	0
146 Shares in the Institute and Coal Trade Chambers Company, Limited (at cost) ...	3,130	0	0			
Investment with the Institute and Coal Trade Chambers Company, Limited (Mortgage)...	1,400	0	0			
				4,530	0	0
(Of the above amount, £350 is due to Life Subscriptions Account, leaving £578 14s. not invested.)						
Furniture Sold				32	2	0
Value of *Transactions* and other Publications, as per Stock Account				454	2	1
Books, Pictures, Maps, Furniture and Fittings				5,150	0	0
				£11,328	16	10

REPRESENTATIVES ON THE COUNCIL OF THE INSTITUTION OF MINING ENGINEERS.

Mr. W. ARMSTRONG moved, and Mr. W. C. BLACKETT seconded, a resolution that the following gentlemen be elected as the representatives of the Institute on the Council of The Institution of Mining Engineers: —

Mr. EMERSON BAINBRIDGE.
Mr. J. BATEY.
Sir LOWTHIAN BELL, BART.
Mr. T. W. BENSON.
Mr. T. FORSTER BROWN.
Mr. A. G. CHARLETON.
Mr. WILLIAM COCHRANE.
Mr. JOHN DAGLISH.
Sir DAVID DALE, BART.
Mr. THOMAS DOUGLAS.
Mr. T. E. FORSTER
Mr. JOHN GERRARD.
Mr. REGINALD GUTHRIE.
Mr. PHILIP KIRKUP.
Mr. C. C. LEACH.
Sir W. T. LEWIS, BART.
Prof. HENRY LOUIS.
Mr. GEORGE MAY.
Mr. HENRY PALMER.
Mr. FRANK R. SIMPSON.
Mr. JOHN B. SIMPSON
Mr. J. G. WEEKS.
Sir THOMAS WRIGHTSON, BART.

The following gentlemen were elected, having been previously nominated: —

MEMBERS —

Mr. WILLIAM BURLISTON-ABIGAIL DINGWALL, Mining Engineer and Mine-owner, P.O. Box 113, Matehuala, State of San Luis Potosi, Mexico.

Mr. GEORGE HENRY GOUGH, Mining Engineer, Umaria, Central Provinces, India, B. W. Railway.

Mr. ALLAN GREENWELL Civil Engineer, 49, Essex Street, Strand, London, W.C.

Mr. FREDERICK CHARLES KEIGHLEY, Superintendent of Mines and Coke-works, Uniontown, Fayette County, Pennsylvania, United States of America.

Mr. DAVID GILLESPIE KERR, Mining and Mechanical Engineer, Marmora, Ontario, Canada.

Mr. D. J. ARTHUR REES, Mining Engineer, 130, Bryn Road, Swansea.

ASSOCIATE MEMBER —

Mr. GEORGE PERCY LISHMAN, Bunker Hill, Fence Houses, County Durham.

ASSOCIATE —

Mr. FARRER WILLIAM MORSON, Mining Student. Glenholm, Crook, County Durham.

STUDENT —

Mr. LIONEL ASHER JACOBS, Mining Student, 3, Thornhill Park, Sunderland.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
SEPTEMBER 15TH, 1900.

MR. R. R. SIMPSON IN THE CHAIR.

ELECTION OF OFFICERS, 1900-1901.

The Committee were elected by ballot as follows:—Mr. T. V. Simpson, chairman, and Messrs. W. R. Bell, J. H. Marr, H. W. Middleton, N. Richardson, Stephen Southern and H. S. Stratton.

Mr. T. V. SIMPSON read the following description of a "Safety-lamp Cabin at Heworth Colliery":—

SAFETY-LAMP CABIN AT HEWORTH COLLIERY.

By THOMAS V. SIMPSON.

The passing of the Coal-mines Regulation Act in 1896, having made it expedient that a new safety-lamp cabin should be erected and that the safety-lamps should be cleaned at the mine, the following arrangements were designed by the manager.

The lamp-cabin (Figs. 1 and 2, Plate I.) is built so as to bring the safety-lamps all to one point for cleaning, and to six points for distribution. For this purpose, the lamp-stands—circular and revolving—are placed in a circle round the cleaning-machine. By this method, a person standing at the machine can, by turning the lamp-stands, almost reach every safety-lamp in the cabin, with very little movement of his position.

There are 12 lamp-stands, each carrying 100 safety-lamps. The stands (Figs. 3 and 4, Plate I.) are made of wrought-iron, fitted with 5 pairs of shelves, one shelf in each pair being placed behind the other; the front one holding the lamp-bottoms and the back one the lamp-tops; and each pair of shelves holds 20 lamps and have numbers attached to them in rotation corresponding with those upon the lamps. The shelves are $10\frac{1}{2}$ inches apart, the lowest being 2 feet 6 inches above the ground. The tops of the stands are joined to each other by means of a circular ring which passes round the cabin, and is fastened by means of stays to the sides of the building. The bottom-ends of the axles of the stands rest in bearings, whose tops are made cup-shaped so as to contain oil.

The walls of the cabin are circular and 18 inches thick (Figs. 1 and 2, Plate I.). There are six windows, at which the lamps are handed out to the workmen, and two stands are conveniently placed adjacent to each window. The entrance-door is placed at one end of the building, and at the opposite end there is a door leading to the repairing-shop. Outside the wall of the cabin, and $4\frac{1}{2}$ feet distant from it, is another wall, 9 inches thick, enclosing a passage-way traversed by the workmen while getting their safety-

lamps. The structure is covered by a glass roof, so as to obtain a good light. The floor is made of cement, and except for the windows, doors and cleaning machine, there is no wood which can become saturated with oil or catch fire.

The double lamp-cleaning machine is driven by a small steam-engine.

The oil-taps are placed at each end of the cleaning-machine, the oil being conveyed in pipes from the store-house.

There are 10 men and boys employed in cleaning the lamps, divided into two shifts of 12 hours each, from 6 to 6 respectively. Two men in each shift hold written authorizations to lock the safety-lamps. One man repairs the lamps during the day-time, when the men are not so busily engaged in cleaning lamps. At night-time, all of the workmen attend to the cleaning of the lamps, the odd hand supplying oil to the lamp-bottoms, while the others, working in couples, clean the lamp-tops.

In order to prevent a lamp from being given out unlocked, one man lights it, while it is on the stand; a second man follows, screws the top and bottom of the lamp together, and places it on the window-sill; the authorized man locks it, and places it on the floor; the last man replaces the lamp in its position on the stands; and thus it is practically impossible for the locking of a lamp to be omitted.

The lighting of the lamps is effected by means of a small tin pot filled with paraffin-oil; a long spout is attached to this pot containing a wick, so that when the lighting-wick is placed next the lamp-wick, a drop of paraffin-oil runs down the spout and falling upon it, causes it to ignite immediately. It is proposed to adopt electric lighting and locking of the lamps. The safety-lamps used at present are fitted with the ordinary screw with a flat head. Colza-oil is used in the lamps.

The cost per lamp per week for the first half year of 1900 was: Materials, 1¼d. labour, 2d.; making a total of 3¼d. per week. The cost is somewhat high, owing to the prevailing rate of wages being above the basis.

The safety-lamps in use are: Mueseler lamps for hewers, stonemen, shifters and wastemen; Donald lamps for deputies and boys; and Marsaut lamps for officials. The revolving-stands used for the various types of safety-lamps are marked on the plan (Fig. 2, Plate I.) H, for hewers; S, for stonemen, etc; W, for wastemen;

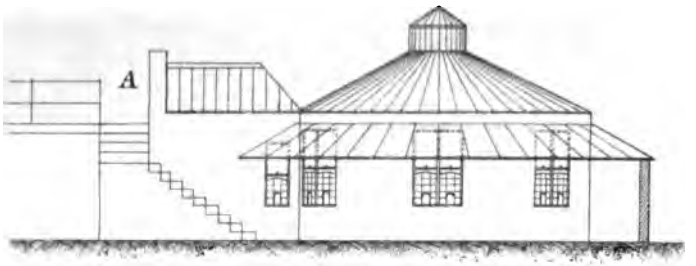
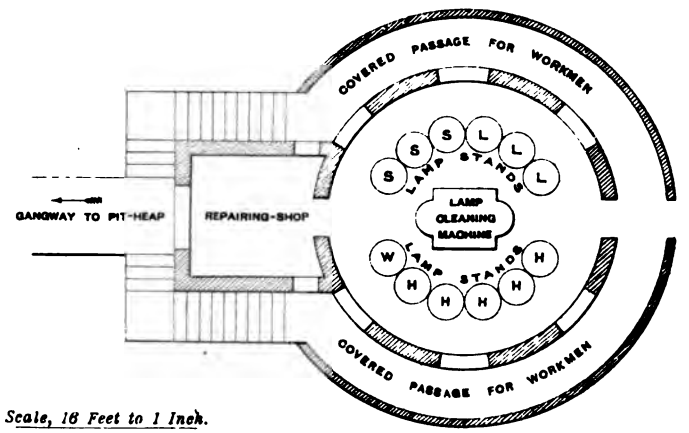


FIG. 1.—ELEVATION OF SAFETY-LAMP CABIN—WITH OUTSIDE WALL REMOVED—SO AS TO SHOW WINDOWS.



Scale, 16 Feet to 1 Inch.

FIG. 2 - PLAN.

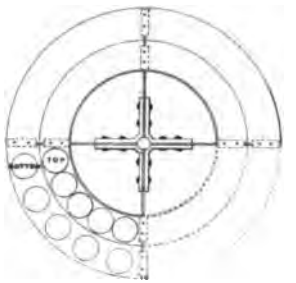
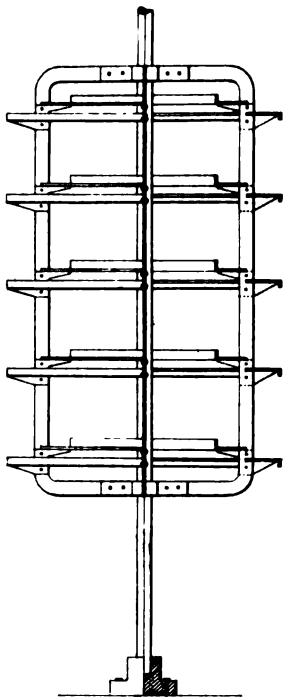


FIG. 3.—PLAN OF LAMP STAND.



Scale, 2 Feet to 1 Inch.

FIG. 4 —SIDE ELEVATION AND SECTION OF LAMP STAND.

And.ᵛ Reid & Comp.ʸ L.ᵗᵈ Newcastle on Tyne

Mining Institute of England Institution of Mining & Mechanical Engineers Transactions 1900.

and L, for lads. The deputies take their lamps home to clean, as they prefer to have their gauzes exceptionally bright and well cleaned.

The workmen, who have safety-lamps, hand in a token before they receive their lamp; the number on the token corresponds to that of their lamp, and when they return the lamp the token is handed to them. The token is placed on a hook attached to a board, placed at the side of every window, so that each stand has its own board containing 100 tokens. Adjacent to each hook is a cardboard label, containing the man's name and number, and by this means it is possible to ascertain who is down the pit and who is not. After receiving his lamp, the workman walks up the stairs to the pit-heap.

Slates, hung between the boards, where the hewers' lamps are kept, record the names of those in opposite shifts, different shifts being written on opposite sides of the slates, so that by turning the slate each week, the workman knows which lamp to light in the fore-shift.

All lamps requiring repairs are given in at the window of the repairing-shop, so as to keep them separate from the others in the cleaning-room.

A barometer, a thermometer, a copy of the abstract of the Coal-mines Regulation Act, and the Special Rules are placed at the end of the gangway, A, adjacent to the lamp-cabin (Fig. 1, Plate I.).

The arrangements just described have been in force for three years and have worked satisfactorily.

A vote of thanks was accorded to Mr. Simpson for his interesting paper.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE GRAND HOTEL, HANLEY, AUGUST 27TH, 1900.

MR. E. B. WAIN IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

MEMBERS—

Mr. TIMON BARKER, Colliery Manager, Fenton.

Mr. PATRICK JOHN BRENNAN, Colliery Manager, Great Fenton Colliery.

Mr. W. B. CLIVE, Clanway Colliery, Tunstall.

Mr. AMOS DANIELS, Colliery Manager, Bunker's Hill Colliery.

Mr. JOHN FAIRS, Colliery Manager, Shelton Iron, Steel and Coal Company, Limited.

Mr. THOMAS GREEN, Assistant Manager, Clanway Colliery, Tunstall.

Mr. ARTHUR HASSAM, General Manager, Madeley Collieries, Newcastle, Staffordshire.

Mr. T. S. HEDLEY, Colliery Manager, Birchenwood Colliery Company. Limited, Kidsgrove.

Mr. CHARLES NEATE, Colliery Manager, Birchenwood Colliery Company, Limited, Kidsgrove.

Mr WM. SLADE OLIVER, Civil Engineer, Stoke-upon-Trent.

Mr. WM. SCRAGG, Colliery Manager, Northwood Colliery, Hanley.

Mr. A. THOMAS, Mining Engineer, East Greta Colliery, near West Maitland, New South Wales.

ASSOCIATE MEMBERS—

Mr. F. L. CORK, Under-manager, Northwood Colliery, Hanley.

Mr. G. P. STREET, General Manager, Knutton Manor Mining Company, Limited, Silverdale.

ASSOCIATES—

Mr. THOMAS DOBSON, Under-manager, Leycett.

Mr. HERBERT OWEN, Under-manager, Wolstanton.

Mr. JOHN TOMLINS, Under-manager, Shelton Iron, Steel and Coal Company, Limited.

Mr. JABEZ WATSON, Under-manager, Little Madeley.

STUDENTS—

Mr. F. L. CORK, Jun., Mining Student, Northwood Colliery, Hanley.

Mr. EDWARD HARTLEY, Mining Student, Berry Hill Collieries, Stoke-upon-Trent.

The officers for the ensuing year were nominated.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD AT THE ROYAL VICTORIA STATION HOTEL, SHEFFIELD,
AUGUST 4th, 1900.

MR. W. H. CHAMBERS, RETIRING-PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

THE LATE MR. T. W. JEFFCOCK.

The CHAIRMAN referred to the sad loss which the members had sustained by the death of Mr. Thomas Jeffcock, on the previous day. He moved that a vote of condolence and an expression of sympathy in her bereavement be sent to Mrs. Jeffcock.

Mr. H. ST. JOHN DURNFORD seconded the motion, which was carried by every member rising in his place.

Messrs. John Nevin and E. W. Thirkell were appointed scrutineers of the balloting-papers for the election of officers for 1900-1901, and of the balloting-papers for representatives on the Council of The Institution of Mining Engineers for 1900-1901.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. JOHN ALLEN, Battery and Assistant Mechanical Engineer, 273, Bury New Road, Higher Broughton, Manchester.

Mr. JOHN D. BAILIE, Electrical Engineer, 13, Peacock's Buildings, Park Row, Leeds.

Mr. SAM BLACKBURN, Colliery Engineer. Thornhill Collieries, Dewsbury.

Mr. JOSEPH FOUNTAIN, Jun., Colliery Proprietor, Haigh Colliery, near Barnsley.

Mr. THOMAS GILL, Colliery Manager, Strafford Collieries, Barnsley.
Mr. JOSEPH INGLEBY, Mechanical Engineer, 20, Mount Street, Manchester.
Mr. STANLEY ROBERT KAY, Mining and Civil Engineer, 1, Albion Place, Leeds.
Mr. WILLIAM JOHN FREDERICK PAYNE, Mine Surveyor, Ackton Hall Colliery, Featherstone.
Mr. CHARLES SNOW, Colliery Manager, South Kirkby Colliery, Wakefield.
Mr. JOSEPH SHEARD, Colliery Manager Farnley Iron Company, Leeds.
Mr. ALFRED WEST, Mining Engineer, Ridings Hall, Birstal, Leeds.
Mr. H. TYLDEN-WRIGHT, Mining Engineer, Monckton Main Colliery, Barnsley.

ASSOCIATES—

Mr. THOMAS HENRY DIXON, Colliery Under-manager, Clifton Hall Colliery, Pendlebury, Manchester.
Mr. ERNEST MARSHALL, Colliery Under-manager, West Riding Collieries, Normanton.
Mr. JOHN WILLIAM SHAW, Colliery Under-manager, Monk Bretton Colliery, Barnsley.

STUDENTS—

Mr. JOSH. HENRY CROSSLEY, Mining Pupil, Ingham Pit, Thornhill Lees, Dewsbury.
Mr. THOMAS NEVIN, Mining Student, Belle Grove, Hopton, Mirfield.

The Annual Report of the Council and the statement of accounts for the past year were read as follows:—

THE COUNCIL'S ANNUAL REPORT.

The Council have pleasure in presenting to the members of the Institute their report on the work of the past year.

The number of members for the past two years is as follows:—

	1898-99.	1899-19 0.
Life Members	4 ...	3
Honorary Members ..	11 ...	Nil.
Members	226 ...	229
Associate Members ...	7 ...	8
Associates	15 .	15
Students	11 ...	9
Totals ...	274	264

The number of members is practically the same as last year, after taking into account the honorary members, as these are now all honorary members of The Institution of Mining Engineers and receive the *Transactions* of that federation.

Of the £27, arrears of subscriptions for 1898-99, £9 have been

collected during the past year. There is, however, a balance of £18, which has now been written off as irrecoverable. The Council again regret to have to state that there has been during the past year some irregularity in the payment of subscriptions, the arrears now amounting to £19 10s. due from 13 members.

The following papers have been read during the past year: —

"Report of Committee upon Recovery-stations."
"Notes on Gob-fires." By Mr. W. H. Chambers.
"Mining Accidents and their Prevention." By Mr. George Farmer.
"Economy in Steam-engine Practice." By Prof. Goodman.
"Description of Sinking Two Shafts through Heavily-watered Strata at Maypole Colliery, Abram, near Wigan, for the Moss Hall Coal Company, Limited." By Mr. James Keen.
"Underground Surveys and their Connexion with the Surface by the Transit Method." By Prof. E. H. Liveing.
"A Power-indicator for Steam-engines." By Prof. W. Ripper.
"Hydraulic Cage-loading and Unloading Apparatus at Cadeby Colliery." By Mr. G. B. Stones.

The September meeting of The Institution of Mining Engineers was held in Sheffield, the arrangements being made by this Institute and the following papers were contributed: —

"Instantaneous Outbursts of Fire-damp and Coal, Broad Oak Colliery." By Mr. John Gerrard.
"Preliminary Study of Recent Borings made in the North of France in search of the Coal-basin." By Prof. J. Gosselet.
"The Rating of Coal-mines." By Mr. Geo. Humphreys-Davies.
"The Devonian Iron-ores of Asturias, Spain." By Mr. J. A. Jones.
"Mining Districts near Kamloops Lake, British Columbia." By Mr. G. F. Monckton.
"Castleton: History, Geology, Minerals and Mining." By Mr. A. H. Stokes.

Excursions were made to the Cadeby Main colliery; Messrs. Hadfield Steel Foundry Company, Limited's East Hecla Works; Messrs. William Cook and Company Limited's Tinsley Steel, Iron and Wire-rope Works; Messrs. John Brown and Company Limited's Atlas Steel Works, and to Castleton.

The Report of the Committee of the North of England Institute of Mining and Mechanical Engineers and the Midland Institute of Mining, Civil and Mechanical Engineers on Mechanical Ventilators has now been issued, and should form a valuable addition to the *Transactions* of the Institution. The thanks of the members are due to Mr. T. W. H. Mitchell, one of the engineers to the Committee, for the efficient manner in which he conducted the experiments.

DR. THE TREASURER (Mr. T. W. H. MITCHELL) IN ACCOUNT WITH THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS, 1899–1900. CR.

	£ s. d.	£ s. d.
July 1st, 1899.		
To Balance at Bankers'	85 11 11	
„ Cash in Treasurer's hands	1 19 3½	
		87 11 2½
June 30th, 1900.		
To Subscriptions for 1899–1900	375 0 0	
„ „ paid in advance for 1900–1901	9 0 0	
„ Arrears	9 0 0	
		393 0 0
„ Sale of Dinner Tickets		11 10 0
„ The Institution of Mining Engineers, Sheffield Meeting, Sale of Dinner Tickets	23 3 0	
„ Members' portion of the Wine-account	3 14 0	
		26 17 0
„ Sale of *Transactions* and Authors' Copies of Papers		2 5 0
„ Letting of Room		1 5 0
„ Bank Interest		5 4 1
		£527 12 3½

Examined and found correct,
J. E. CHAMBERS,
E. W. THIRKELL,
July 30th, 1900. AUDITORS.

	£ s. d.	£ s. d.
June 30th, 1900.		
By The Institution of Mining Engineers:—		
Call of 19s. per Member on 261 Members for 1899-1900	247 19 0	
Balance of Call for 1898-99	5 14 0	
Excerpt *Transactions*, etc.	14 6 9	
Reducing Plates	0 10 0	
Proportion of cost of Exchanging *Transactions* with other Societies	2 16	
		271 6 5
„ Annual Dinner		15 6 0
„ Printing and Stationery		10 2 4
„ Rent of Room		12 0 0
„ Reporter		8 10 0
„ Insurance		1 11 6
„ Cleaning		0 5 0
„ Gas Company		0 5 0
„ Hire of Rooms for Meetings in Leeds, Sheffield and Wakefield		1 9 6
„ Dinner and Expenses in connection with the Sheffield Meeting of The Institution of Mining Engineers		33 2 5
„ Secretary's Salary	£50 0 0	
„ „ Expenses	5 4 5	
		55 4 5
„ Stamps, Telegrams, Carriage, Wrappers and Sundries		11 12 8
„ Balance at Bankers'	£105 15 9	
„ Cash in Treasurer's hands	1 1 3½	
		106 17 0½
		£527 12 3½

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.
GENERAL STATEMENT, 1899–1900.

LIABILITIES.				ASSETS.			
1900.	£	s.	d.	1900.	£	s.	d.
June 30.—None.				June 30.—By Cash in Bank	105	15	9
„ To Balance, being capital	464	15	0½	„ „ „ Treasurer's hands ...	1	1	3½
					106	17	0½
				„ „ Value of 6,879 parts of *Transactions*, at 1s. ...	343	19	0
				„ „ Value of 115 Copies of Narratives of Sudden Outbursts of Gas, at 1s.	5	15	0
				„ „ Value of 116 Copies of Committee's Report on Safety-lamps, at 1s.	5	16	0
				„ „ Value of 16 Copies of Report of French Commission on Use of Explosives, at 3s. ...	2	8	0
					357	18	0
	£464	15	0½		£464	15	0½

Examined and found correct,
J. E. CHAMBERS,
E. W. THIRKELL,
July 30th, 1900. AUDITORS.

Arrangements are being made at the West Riding collieries, Normanton, through the kindness of Mr. W. E. Garforth, for conducting experiments, upon as practical a scale as possible, for the recovery of mines after explosions, the results of which will be communicated to the members in due course.

The Council would again impress upon the members the desirability of obtaining new members, and also of contributing papers, in order to carry on successfully the work of the Institute, representing as it does one of the most important coal-fields in Great Britain.

There is a balance in the bank of £105 15s. 9d. against £85 11s. 11d. at the end of last year.

The Council have had under consideration the desirability of altering the rules in conformity with the rules of The Institution of Mining Engineers, and proposals to this effect will be submitted to the members at the Annual Meeting.

The question of the correlation of the Lancashire and Yorkshire coal-fields has now been referred to the Manchester Geological Society as the committee appointed by this Institute has completed its work so far as the Yorkshire sections are concerned.

The CHAIRMAN (Mr. W. H. Chambers), in moving the adoption of the report and accounts, said that financially the Institute was in about the same position as last year, although there was a little more credit-balance at the bank, in consequence of subscriptions being paid in advance, and the assets were practically the same.

Mr. M. H. HABERSHON seconded the motion, which was agreed to.

ELECTION OF OFFICERS FOR 1900-1901.

The SCRUTINEERS reported the result of the election as follows:—

PRESIDENT:

Mr. JOHN GERRARD.

VICE-PRESIDENTS:

Mr. H. ST. JOHN DURNFORD. Mr. J. E. CHAMBERS.

Mr. WALTER HARGREAVES.

COUNCIL:

Mr. L. DOBINSON.	Mr. J. L. MARSHALL.
Mr. C. C. ELLISON.	Mr. H. B. NASH.
Mr. F. W. HARDWICK.	Mr. W. M. REYNOLDS.
Mr. J. KNOWLES.	Mr. J. R. ROBINSON WILSON.

SECRETARY AND TREASURER:
Mr. T. W. H. MITCHELL.

Mr. C. E. RHODES said that it needed no words of his to emphasize the gratitude of the members for Mr. Chambers' services. He did not know any President who had had a wider experience of practical mining than Mr. Chambers, and none had reflected greater credit on the Institute while occupying the chair. He had pleasure in moving a vote of thanks to Mr. Chambers.

Mr. JOHN NEVIN, in seconding the motion, said that Mr. Chambers had been successful in keeping up the interest of their proceedings during the two years that he had held office, and the members were obliged to him for the time and attention which he had given to the duties of his post.

The motion was carried.

Mr. W. H. CHAMBERS thanked the members for the great kindness shown him during his term of office; it had been a great pleasure to him to occupy that chair, and an honour which he had fully appreciated; he would continue to take an interest in the Institute after he had vacated the chair, and would be glad to do anything that he could for its welfare and to support his successors as he had been supported.

REPRESENTATIVES ON THE COUNCIL OF THE INSTITUTION OF MINING ENGINEERS, 1900-1901.

The SCRUTINEERS reported the result of the election as follows:—

Mr. W. H. CHAMBERS.	Mr. JOHN GERRARD.
Mr. H. ST. JOHN DURNFORD.	Mr. JOHN NEVIN.
Mr. W. E. GARFORTH.	Mr. F. N. WARDELL.

Mr. ARTHUR T. THOMSON's paper on "Underground Electric Haulage at Manvers Main Collieries" was read as follows:—

UNDERGROUND ELECTRIC HAULAGE AT MANVERS MAIN COLLIERIES.

By ARTHUR T. THOMSON.

The writer is aware, when giving the following short description of the electric haulage-installation at Manvers Main No. 1 pit, that the system is no novelty; but he is hopeful that his paper may be of interest, since it describes an application of electric haulage as an auxiliary to the existing engine-plane haulage, as a means of distributing the empty corves and collecting the full ones to the main engine-plane landings: the distance to these landings from the pit-bottom being the limit at which the trains, going and returning, can keep the shaft-cages continually working. It is needless to point out that the electric auxiliary haulage replaces a large number of ponies, which would otherwise be required to do the work.

The districts served by the electric-motors are shown in Figs. 1 and 2 (Plate II.) and are known as the sixth and seventh south districts respectively.

In the sixth south district (Fig. 1, Plate II.), the ropes are at present working on the main-and-tail system along a level-gate road, A, through the goaf, to a landing about 1,500 feet in-bye. The trains, which consist of about 50 corves, carrying say 30 tons of coal, are hauled along a single line of rails between the landings, at an average speed of 5 miles per hour. The gradients vary, but are generally in favour of the full train, and the effort required for the work is 40 horsepower to start the load, about 25 horsepower on the run out-bye, and 47 horsepower when pulling the train into the main engine-plane landing. At present about 10 trains per day are hauled by the motor which is only running for about a quarter of the shift. In time, this road will be abandoned and the middle road, B (Fig. 1, Plate II.), which is nearly level, will take its place. The lower road, C (Fig. 1, Plate II.), will in future be worked from this motor, and as the average dip

is about 1 in 25, a main rope only will be used. It is intended that, eventually, about 20 trains per day shall be collected by this motor to the main engine-plane landing.

The motor working the seventh south district (Fig. 2, Plate II.) is placed at the junction of the level engine-plane with the slant engine-plane. It works the main-and-tail ropes along the level engine-plane to the landing, a distance of about 900 feet. Some 10 trains of 20 corves are at present hauled daily upon this road, but as the district is extended the haulage will be extended along the lower cross-gate road out of the in-bye landing and the output considerably increased. About 28 horsepower is necessary to do the work on this engine-plane.

The main rope only is used in the slant district to haul the corves to the main engine-plane landing, which is situated 1,200 feet below the motor. This landing will be moved up the plane to the point, A (Fig. 2, Plate II.), and the motor will then draw all the coal from the slant district to that point. At present about 8 trains of 20 corves are hauled up the dip gate-road, B (Fig. 2, Plate II.), from a landing 825 feet down, the load being then dropped back into the present main engine-plane landing. The road, B, has an average gradient of 1 in 20 against the full load, and the power required to start the standing train is 58 horsepower, which, very shortly after the train is in motion, falls to 36 horsepower.

Neither of the motors is working up to its full capacity: they have been working satisfactorily during the two years that the plant has been in use.

A general idea of the generating-plant and the underground distribution of the current to the motors is shewn in Fig. 3 (Plate II.).

The two-pole continuous-current dynamo with a drum-armature, has an output of 160 ampères at 600 volts at full load, and 560 volts on an open circuit, the field-winding being over compounded by 6 per cent. so as to keep the volts constant at the feeding-point, and is driven direct from the engine fly-wheel by 8 ropes, 1¼ inches in diameter.

The vertical semi-marine engine, with piston-valves, has a cylinder 21 inches in diameter by 21 inches stroke, and is governed by a shaft-governor actuating an inner piston-valve. Steam is used at a pressure of 70 pounds per square inch, and at 154 revolu-

tions per minute the engine develops 145 horsepower; but it is capable, together with the rest of the system, of working for a period, considerably above this duty.

Callender cables, insulated with vulcanized bitumen and armoured with locked-coil steel-wire, are used in the shaft, and with galvanized wire armouring on the underground roads. Four cables are carried down the shaft and of these two only are in use. They are suspended by means of wooden clamps, secured to the back of the cage-guide buntings: there are three points of attachment, namely, at the top, at one-third, and at two-thirds of the depth. The clamps are made of oak, two pieces being bolted together with the cable lying in grooves between them (Figs. 4 and 5, Plate II.), the grip on the cable being sufficient to prevent it from slipping, and not so great as to damage it by distortion.

Along the underground roads, the cables are suspended at intervals of about 15 feet upon wooden cleats, nailed to props and bar-legs. In order that the cables may not be damaged by any undue stress (which might be put upon them by a fall of roof or other causes), about 5 per cent. of over length of cable is suspended, which allows it to sag slightly between the supports; further, the cleats will readily draw away from the props, and allow a considerable length of cable to be released from the supports and the stress removed. The method of suspension is shewn in Figs. 6, 7 and 8 (Plate II.).

At positions shewn on Fig. 3 (Plate II.), switches and fuses are placed in circuit, so that in case of mishap the current can be cut-out without undue delay; whilst, in front of each motor-station, a switch is fixed so that the motors, liquid resistances, and other electrical gear may be examined in safety. The motor-stations and landings are lighted electrically, 5 lamps in series, and the current for the lighting is taken off the cables, in front of the last-mentioned switches, which can be worked without extinguishing the electric lamps. All switches are of the double-pole type, and those which are used in a closed circuit are contained in gas-tight metal cases, the cables being entered into these cases, either through stuffing-boxes and glands, or through pockets, into which liquid bitumen was afterwards run, to act as a seal (Fig. 9, Plate II.). Incidentally it may be mentioned that in this latter operation an electric frying-pan was used with satisfactory results.

The joints in the cables are made by clamps, enclosed in cast-iron boxes which are filled with insulating oil, and in order to prevent the cable from being drawn out of these clamps, coned wedges and tightening plates securely grasp the armouring of the cable at either end of the joint-boxes, any stress which may come upon the cable being thus transmitted through the cast-iron box, and not through the clamped copper cores.

The electric current is carried from the dynamo to the switch-box at the pit-bottom by armoured cable (37 wires of 0·082 inch in diameter), the length of the cable to this point, lead and return, being 2,100 feet; and thence to the distribution-switch at the junction of the sixth south road with the travelling road, a further distance, lead and return, of 7,002 feet, the cable has 37 wires of No. 13 gauge. The electromotive force is 560 volts, or a loss of potential at this point at full load, of 40 volts, due of course, to circuit-resistance. Thence, the current is carried to the sixth south station, a distance of 5,298 feet, lead and return, by a cable (37 wires of No. 15 gauge); and to the seventh south station, 8,160 feet, lead and return, by a cable (37 wires of No. 13 gauge), circuit-resistance causing a further loss of potential of 20 volts to either station, the working electromotive force at the motors being 540 volts.

The motor-stations are walled with brick and roofed with steel-girders and, as before mentioned, are situated at the outbye-ends of the main engine-plane landings, so that the full corves may be hauled into positions for the main engine-plane ropes to be attached.

The hauling-engines, driven by the electric motors by means of belt-pulleys and spur-gearing, consist of 2 drums, each 3 feet in diameter. The drums can be thrown in and out of gear by friction-clutches, which grip under the brake-rims of the drums, powerful strap-brakes, capable of holding the train on any of the gradients being provided (Fig. 10, Plate II.). The bed-plates are bolted to heavy timber foundation-frames which are built into the side-walls.

The motors, of 50 horsepower when running at 600 revolutions per minute, are capable of carrying a 50 per cent. overload for 10 minutes without undue heating. They have drum-armatures, and the field-magnets, which are shunt-wound, are compounded

...id Electric Haulage," &c.

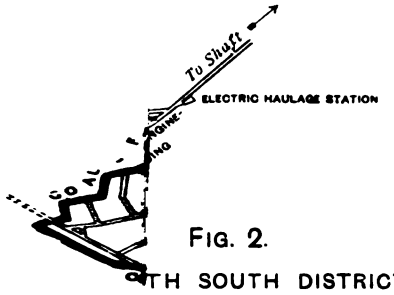


FIG. 2.

...TH SOUTH DISTRICT.

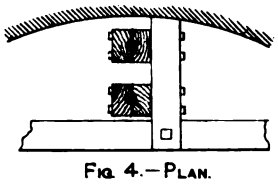


FIG. 4.—PLAN.

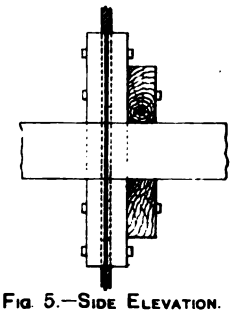
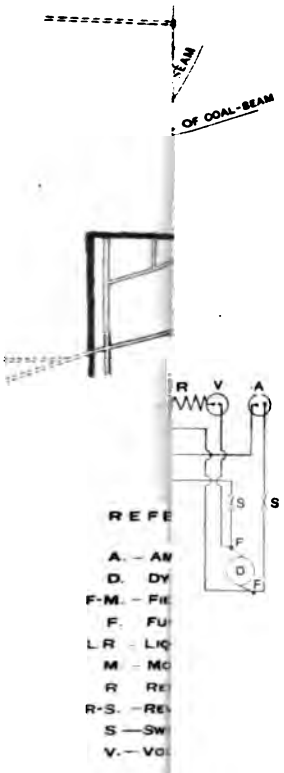


FIG. 5.—SIDE ELEVATION.

Scale, 4 Feet to 1 Inch.



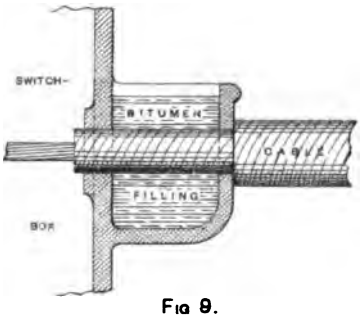


FIG 9.

Scale, 8 Inches to 1 Inch.

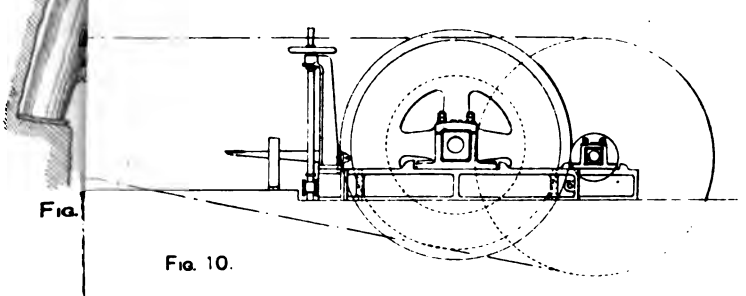


FIG. 10.

with a few series turns to obtain a satisfactory torque at starting. The motors are enclosed in gas-tight cases, so that any sudden outburst of fire-damp may not be ignited by sparking at the brushes, but allow the attendant ample time to cut out the armature-circuit should such an outburst occur. The cases are made in halves and are readily removable, the field-magnets are also constructed to part at the centre-line and slide forwards, in order that, if necessary, the armatures may be removed with the least expenditure of time and labour.

The shunt or field-circuit is controlled by a double-pole switch and is so interlocked with the other switch-board appliances, that the armature-circuit cannot be closed until the field is excited, nor can the shunt-circuit be opened whilst the armature-circuit is closed. The field-magnets are left excited throughout the day's work, and in order that the shunt-circuit may be opened without sparking, non-inductive resistances are placed in parallel with the field-coils at the moment of break: the resistance of the field-coils and the non-inductive resistances being of course equal. These switches are actuated in closed circuit, and are contained in gas-tight cases. The remainder of the switch-board appliances consist of a double-pole resistance and a double-pole reversing-switch for the armature-circuit.

The resistances for regulating the armature-current are of the Lyons liquid type, wherein a leaden cone suspended on a copper conductor, is gradually lowered through a slightly alkaline (soda) solution, until metallic contact is made with a leaden cup, fixed at the bottom of the stoneware vessel, in which the liquid is contained. By varying the relative positions of the cone to the cup through the liquid, a very fair control over the armature-current is obtained. To obviate danger from sparking, at "make" and "break," the vessels are covered with gas-tight covers, the copper-rod conductor working through an insulated gland, and the steam-escape opening is covered with gauze. The leaden cones are lowered and raised through the liquid by means of a small worm and worm-wheel, but this cannot be effected, as previously pointed out, until the shunt-circuit is closed and the reversing-switch for the armature-current is in proper position. The least motion of the worm-gear instantly locks these two switches. As the reversing-switch can only be moved when the armature-circuit is cut out, it is left open to the air.

Mr. R. Holiday (Ackton Hall Colliery) asked whether the shaft in which the cables were suspended was wet. The cables were fastened by wooden clamps; however well the cables might be insulated, if there was moisture as well as dust, it collected on the clamps, and with a high voltage it was only a question of time before the insulation broke down. The mains were suspended along the underground roads at intervals of 15 feet, upon wooden cleats, but he recommended that they should be hung on tar-bands fastened with nails. If anything happened the wooden cleats would hold, and the cables would probably be damaged; whereas if they were suspended from nails and anything happened the tar-band might be broken or the nails drawn out and a length of cable allowed to fall upon the ground; and when repairing the roof, the cable could be lifted off the nails, and laid upon the floor. Too many switches seemed to be shewn: in Fig. 3 (Plate II.), there was a main switch controlled by another switch a few feet off. The field-magnets were left excited throughout the day's work, and the power used for this purpose, due to the special arrangement of resistances, would reduce the efficiency of the machine. He did not see why a reversing-motor was used; there were two loose drums and with a motor always running in one direction, and with care in winding both the ropes on the drums in the same direction, the motion could be reversed without using a reversing-switch—which seemed an unnecessary adjunct.

The Chairman (Mr. W. H. Chambers) moved a vote of thanks to Mr. Thomson for his interesting paper on an interesting subject.

Mr. H. St. John Durnford seconded the motion, which was approved.

ALTERATIONS OF RULES.

Mr. J. R. Robinson Wilson, in accordance with notice given, moved that the Rules as amended, printed, and now in the hands of the members, be adopted as the Rules of the Institute.

Mr. H. B. Nash seconded the motion, which was adopted.

The Annual Dinner was held in the evening at the Royal Victoria Station Hotel, Sheffield.

THE MINING INSTITUTE OF SCOTLAND.

ANNUAL EXCURSION,
AUGUST 9TH, 1900.

About 100 members, conveyed by train from different parts of the country, met at Edinburgh, and were conveyed in brakes to the Summerlee and Mossend Iron and Steel Company's Prestongrange Colliery, near Prestonpans, where they were met by Mr. George Russell and Mr. David M. Mowat and shewn over the works.

PRESTONGRANGE COLLIERY.

Prestongrange colliery is situated in the county of Haddington, about 7½ miles east of Edinburgh, and about midway between Musselburgh and Prestonpans, on the southern shore of the Firth of Forth. The mineral field extends to about 2,500 acres, a large portion of it lying under the Firth.

The workable seams of coal are all in the Carboniferous Limestone Series, immediately below the Millstone Grit. The mineral field forms the eastern side of the great trough which runs up the valley of the Esk. On the western side, towards the Esk, the inclination is considerable, in some parts being as high as 1 in 2½; while on the eastern side the strata dip gently eastwards towards Tranent and Cockenzie.* The seams presently being worked are the Great seam, the Clay seam, the Five-feet seam, the Jewel seam, and the Beggar seam. In Morrison's Haven shaft the section is as follows, namely:—

Great Seam, Coal 6½ to 8 Feet, Fire-clay, 0 to 2 Feet, at ...	420 Feet.
Clay Seam, Coal, 2½ Feet, Fire-clay, 1½ Feet, at	540 ,,
Five-feet Seam, Coal, 3 Feet 2 Inches, at	570 ,,
Jewel Seam, Coal 3 Feet 7 Inches to 4 Feet, at	744 ,,
Beggar Seam, Coal, 3 Feet 2 Inches, at	780 ,,

Besides these, there are a number of coal-seams over 2 feet in thickness.

* *Trans. Inst. M.E.*, vol. vi., plate ix., page 392.

The output is derived principally from the Great and Jewel seams. The Clay and Five-feet seams are being worked under the land, and the Great, Jewel and Beggar seams under the sea.

There are two shafts; one partly 10 feet in diameter and partly 10 feet square, was sunk to the Great seam by Mr. Matthias Dunn about 1820, and is used as an upcast and pumping-shaft. The winding-shaft which was sunk in 1872 measures 16 feet by 10 feet. The cages are double-decked, with two hutches end to end on each deck. The hutches can take about 9 cwts. of coal.

The Great seam is worked on the stoop-and-room system. In the workings under the sea, the stoops are formed 45 feet square with rooms 15 feet wide, and the stoops are left. The other seams are all worked on the longwall system, with walls about 50 feet long. Where coal is now being worked, the depth under the sea-bed varies from 360 to 900 feet.

The vertical winding-engine, with overhead drum, has 2 cylinders, 25 inches in diameter with a stroke of 6 feet, and the drums are 10 feet in diameter on the Great seam side, and 13½ feet in diameter on the Jewel seam side.

The shaft-pumping is performed by a Cornish engine with a single cylinder, 70 inches in diameter with a stroke of 12 feet. There are four plunger-lifts, three 22 inches in diameter, and one 17 inches in diameter with a stroke of 10 feet. The dook-pumping is performed by compressed-air and hydraulic pumps. There are two air-compressors on the surface, having each a 20 inches steam-cylinder and 18 inches air-cylinder with a stroke of 4 feet, and these drive dook-pumps in the Great seam. There is a Brown hydraulic pump in the Jewel seam, driven by surplus water run down from the Great seam to the Jewel seam, to balance the shaft-pumps.

There is an hydraulic installation in course of erection, intended to supplement the shaft-pumps and to take the place of the compressed-air pumps. The power plant consists of an horizontal engine with 2 cylinders, 27 inches in diameter by 5 feet stroke, driving the pumps directly from the piston-rods so as to maintain a constant pressure of 1,000 pounds per square inch in the hydraulic mains. The Brown pumps to supplement the shaft-pumps are placed, one in the Great seam to pump 500 gallons per minute to a vertical height of 600 feet, and one in the Jewel seam to raise 200 gallons per minute to a vertical height of 216 feet.

The Great seam pump is in position, but is not yet connected, and the Jewel seam pump was seen on the surface.

All the underground haulage is effected on the endless-rope system with single hutches, the rope-speed being about 1¼ miles per hour. The rope is placed under the hutches which are attached to the rope by Smallman clips. The horizontal hauling-engine on the surface has 2 cylinders, 22 inches in diameter by 5 feet stroke. The Thorncliffe driving clip-pulley, with mild steel liners in the cheeks, is 8 feet in diameter and is placed on the crank-shaft. It is intended ultimately to drive this engine at 21 revolutions per minute, giving a speed of 6 miles per hour to the band-rope. Presently the speed is 14 or 15 revolutions per minute, giving the band-rope a speed of about 4 miles per hour. The band-rope, ⅞ inch in diameter, of galvanized patent improved steel, has been in use for 26 months, during which time the splice has been renewed 3 or 4 times. It has travelled about 55,000 miles and is in fairly good condition. Including the driving pulleys, the rope passes over 8 pulleys 8 feet in diameter and one 12 feet in diameter. There is gearing in both seams for reducing the speed of the haulage-ropes to one third of that of the band-rope. In the Great seam, this is effected by passing the band-rope round a 12 feet pulley driving a C pulley, 4 feet in diameter, for the haulage on the same shaft. In the Jewel seam, where the haulage will ultimately be heavy, the speed is reduced by spur-gearing, all the clip-pulleys being 8 feet in diameter, so as to allow of a large haulage-rope being used. The underground haulage-ropes now in use are all 2½ inches in circumference.

The ventilation of the colliery is produced by a Guibal fan, 22 feet in diameter by 7 feet wide, running at about 60 revolutions per minute. The fan is driven by an engine with a cylinder 18 inches in diameter and 18 inches stroke.

Steam is generated for the colliery and brickworks at a range of 10 Lancashire boilers, each 28 feet long by 7½ feet in diameter. The chimney is 200 feet high, 17 feet square outside at the base, and 9 feet square inside at the top. The steam-pressure is 70 pounds per square inch. On account of the saltness and hardness of the pit-water, condensers have been erected to obtain a supply of hot distilled water for the boilers.

On the pithead, the loaded hutches gravitate to the tumblers and the empty hutches are returned to the back scaffold by a creeper.

There are 6 self-acting tumblers, 5 of which are used for coal, and 1 for fire-clay. There are 5 double shaking-screens with various sizes of perforation. The coal is hand-picked on 5 travelling tables with lowering ends to prevent or reduce breakage at the wagons. The dross is carried from all the screens by a scraper-conveyor to the elevator-pit, whence it is raised by an elevator capable of raising 50 tons per hour. It is then divided into six sizes by a revolving riddle composed of perforated steel plates, the perforations being kept open by means of a blower. Five sizes of dross are washed in bash-tanks and delivered into hoppers, the unwashed gum-coal being conveyed to the boiler dross-hole by a scraper-conveyor. Provision is also made for loading large and small coal into carts by means of 3 coal-screens and 4 hoppers for washed dross.

Composition-bricks, fire-bricks, covers, blocks, pipes, traps, vent-linings, chimney-cans, and fancy-ware are made from the blaes and fire-clay drawn from the mine. These are all hand-made, except the pipes and vent-linings, which are made by a Titley pipe-machine having a cylinder 42 inches in diameter. The green-ware is all steam-dried and burnt in circular and Newcastle kilns.

At the harbour, provision is made for loading and unloading vessels, either afloat or on the ground. One of the berths is furnished with a movable shoot so that steamers may be loaded and bunkered without being shifted. The capacity of this shoot is about 90 tons per hour.

There are about 250 workmen's houses connected with the colliery, besides a block of 32 now in course of construction. Those recently built are two-storied, two-roomed houses of brick.

All the surface-plant, the brickworks, office and harbour are lighted by electricity. The installation consists of a Silvertown dynamo with an output of 370 ampères at 60 volts at 460 revolutions per minute. There are 10 arc-lamps and 160 incandescent-lamps. This plant is driven by an engine, with a cylinder 13 inches in diameter and 3 feet stroke, running at 60 revolutions per minute.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD AT PRESTONGRANGE COLLIERY, AUGUST 9th, 1900.

MR. JAMES T. FORGIE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. THOMAS ARNOTT, 109, Hope Street, Glasgow
Mr. WM. DRYSDALE, Ayr Colliery, Annbank.
Mr. THOMAS HILL, Burnfoothill, Dunaskin, Ayr.
Mr. P. L. NAISMITH, Lethbridge, Alta, Canada.
Mr. JAMES ORCHARD OXLEY, 31, Lombard Street, London, E.C.
Mr. JAMES R. WILSON, Main Street, Bothwell.

ASSOCIATE MEMBER—

Mr. ADAM NIMMO, 21, Bothwell Street, Glasgow.

ASSOCIATES—

Mr. ROBERT LIVINGSTONE, Lethbridge, Alta, Canada.
Mr. JAMES MCCUBBREY, Belvidere Terrace, Bellshill.
Mr. FRANCIS DICKIE WEIR, Portland Ironworks, Hurlford.

STUDENT—

Mr. JOHN WILSON, 177, South Cumberland Street, Glasgow.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE HALL OF THE INSTITUTE, HAMILTON,
OCTOBER 11TH, 1900.

MR. THOMAS THOMSON IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected by ballot:—

MEMBERS—

Mr. JOHN COWIE, Alexandria Cottage, Galston.
Mr. JAMES THOMSON DIXON, Cranbrook, East Kootenay, British Columbia.
Mr. GEORGE HUTCHISON, Neilston Colliery, Kilsyth.
Mr. JOHN KENNEDY, Broad Street House, New Broad Street, London, E.C.
Mr. JAMES KIRKPATRICK, Glenclelland Colliery, Wishaw.
Mr. WILLIAM LANE, 30, Florence Road, Wortley, Leeds.
Mr. JOHN POLLOCK, 83, Woodside Street, Coatbridge.

ASSOCIATE MEMBER—

Mr. JOHN SIMPSON, North Bank House, Prestonpans.

ASSOCIATE—

Mr. JAMES MCGINTY, Blair Bridge, Coatbridge.

STUDENT—

Mr. ANDREW WHITE BAXTER, 134, Low Waters, Hamilton.

The discussion of Mr. W. D. L. Hardie's paper on "Endless-rope Haulage at Lethbridge Colliery" was closed, a hearty vote of thanks being awarded to the author.

DISCUSSION OF MR. T. H. MOTTRAM'S PAPER ON "EXPLOSIONS OF FIRE-DAMP AND COAL-DUST IN THE WEST OF SCOTLAND."*

Mr. MOTTRAM, replying to remarks made at previous meetings, said that there were one or two points to which he would like to refer briefly. The first was the reference made by Mr. R. W. Dron

* *Trans. Inst. M.E.*, vol. xviii., pages 186, 325 and 390.

to the Annual Report for 1890, of Mr. J. T. Robson, H.M. inspector of mines for South Wales, in which he stated that "discarding explosions, and including all other underground fatal accidents and loss of life, it appears that naked-light collieries were 25 per cent. and 28 per cent. safer respectively, calculated on the persons employed, and 34 per cent. and 37 per cent. safer, respectively, on the quantity of minerals raised."* These figures were interesting, but over much stress should not be laid upon the comparison, because the figures apparently applied to one year only, and there was no evidence to show that the roof and other physical conditions were the same in both groups of mines. In order to ascertain whether closed lights really lead to more accidents by falls, the most reliable test was to take mines in which the lighting had been changed from open lights to safety-lamps and to compare the results over a period of years.† He had made such a comparison, and as members will recollect, the accidents by falls were found to have been fewer. Referring again to Mr. Dron's quotation, the quoted paragraph should be read in conjunction with Mr. J. T. Robson's remarks on page 11 of the same report, in which he states as to deaths by falls, that "they are more numerous in good and fairly good roofs than in acknowledged bad roofs. . . These facts and a careful study of the whole circumstances only corroborate what the experience of previous years has shown, namely, that a majority of fatalities by falls occur from an overestimate of the natural security of the newly-exposed roof and from the inability to detect latent weaknesses, thus leaving it insufficiently supported by propping." And further, he (Mr. Mottram) was not sure, although Mr. J. T. Robson gave the comparison referred to by Mr. R. W. Dron, that he made the same inference as Mr. Dron; for in the same report it will be noticed that Mr. Robson, like many others, favours the safety-lamp, and he would not do so if there were disadvantages as to the safety as a whole. In other words, in mines known to produce fire-damp there is more risk to life and limb by using open lights.

Mr. Geo. A. Mitchell had asked whether it was not a fact that accidents by falls had materially decreased both in pits where naked lights and in those where safety-lamps were used. The comparative tables for the United Kingdom showed of late years

* *Trans. Inst. M.E.*, vol. xviii., page 327.

† *Ibid.*, vol. xviii., page 325.

a slight decrease in the deaths by falls, but these tables did not show whether or not the improvement had been greater in open-light pits than where safety-lamps were used.* In the West of Scotland mines-inspection district, from 1895 to 1898, there was an increase in the death-rate by falls. Safety-lamps were introduced into 7 collieries in 1891 and thereafter the accidents were fewer at those collieries. It is evident that the increase in the death-rate from 1895 to 1898 could not be attributed to the increased use of safety-lamps, when such lamps had been in use for some years; and, if the use of safety-lamps caused an increase in accidents by falls, this increase would have become apparent at once when the workers were unaccustomed to the use of the enclosed light. Some members may suggest that if safety-lamps had not been in use there would have been fewer accidents. To this, he would reply that while there was a temporary increase in the number of accidents by falls in the West of Scotland mines-inspection district as a whole, four to eight years later, the pits where safety-lamps were adopted were not responsible for the increase. He ventured to suggest at a previous meeting that the decrease in the number of accidents might be due to better discipline following the introduction of closed lights, and he thought the only inference that could be drawn from the facts which he had cited was that actual experience showed that the adoption of safety-lamps in a mine implied no increase in the number of accidents by falls.

Mr. J. T. Forgie had asked for the definition of a fiery mine.† The legislature had not yet attempted definitely to define a fiery mine or a non-fiery mine, but it was certain that the latter term, by which naked-light pits were generally known, was in some cases a misnomer, as serious and fatal accidents from fire-damp occurred from time to time in mines bearing that name. It would be comparatively easy to define a non-fiery mine, and by leaving out of the same category all other pits, arrive at a simple definition of a fiery mine, but for the varying conditions under which fire-damp was sometimes found. For example, a small quantity of fire-damp under the conditions prevailing in some mines—where there was coal-dust for instance, might be comparatively safe if unaccompanied by so dangerous an element; while in other

* *Trans. Inst. M.E.*, vol. xviii., page 390.

† *Ibid.* vol. xviii., page 328.

cases the ignition or presence of fire-damp might be very far indeed removed from, and have little or no connection with present or future workings. Such varying conditions as these rendered it difficult to frame a definition of a fiery mine agreeable to all parties, particularly if such definition implied the use of closed lights. At the present time the fairest way of dealing with the so-called non-fiery mine, was to consider the past record and present condition of each mine and act accordingly by Special Rule, not of course forgetting that the present provisions of the Coal-mines Regulation Act made the use of safety-lamps compulsory under certain other conditions as laid down by No. 8 General Rule. Efforts in this direction had been made, and it was hoped that before long something definite might be agreed upon.

In reference to Mr. D. M. Mowat's observations on No. 8 General Rule (which provided that whenever a safety-lamp was used in a working-place safety-lamps must also be used between that place and the return air-course); he agreed that sometimes this rule might seem to be a hardship and in some cases might limit the use of closed lights. In other instances, however, the same General Rule must have been a blessing in disguise, for not infrequently, when elsewhere it had been contravened, serious explosions had occurred; and for every case in which the same rule might have prevented the use of a closed light, probably, in ten others, it had been the means of introducing more safety-lamps than any other General Rule in the Coal-mines Regulation Act.

The discussion was closed, and a hearty vote of thanks given to Mr. Mottram for his valuable paper.

DISCUSSION OF MR. ROBT. W. DRON'S PAPER ON "THE PROBABLE DURATION OF THE SCOTTISH COAL-FIELDS."*

Mr. R. W. Dron, replying to the discussion, wrote that Mr. J. Hamilton mentioned the large amount of loss in the early workings of coal, but it was worth noting that considerable areas of pillars left in by early miners were now being recovered to advantage.†

* *Trans. Inst. M.E.*, vol. xviii., pages 194, 331 and 393; and vol. xix., page 57.

† *Ibid.*, vol. xviii., page 333.

Mr. G. A. Mitchell had asked what were the proportions of output wrought from each county during the years from 1878 to 1882: from the figures given in Table VII., it would be seen that in most cases there was no material difference in the proportions.*

TABLE VII.—Showing Proportion of Total Output produced from each County.

County.	Output for Years 1878 to 1896.	Output for Years 1878 to 1882.
	Per cent.	Per cent.
Ayr	14·4	17·0
Dumbarton	1·4	1·2
Lanark	55·9	55·8
Renfrew	0·3	0·6
Stirling	6·1	5·4
Edinburgh	3·7	4·2
Fife and Kinross	11·9	10·3
Haddington	1·2	1·2
Linlithgow	2·8	2·4
Other counties	2·3	1·9

The area covered by Permian rocks, in Dumfriesshire, extended over about 80 square miles, but it did not follow that Coal-measures would be found throughout the whole of this area. The Permian rocks are lying unconformably upon the Coal-measures, and at the western margin of the basin, they are resting on the Lower Limestones. The estimated quantity in Dumfriesshire was shown in Table IV.† In the Dalmellington and Patna area, referred to by Mr. W. Smith,‡ the district was divided practically on the lines he suggested; and most of the district lying to the north-east of Patna, where there were intrusive sheets of basalt, had been included in Table I. as "North of Dalmellington"; and, as would be seen on referring to the Table, only 5 feet of "thin and uncertain coal-seams" had been estimated for that area. Although the 1,200 feet bore-hole in the south-western corner of the Dalmellington coal-field showed, as Mr. Smith stated, that that particular area was burnt, this could hardly be taken as evidence that the whole area of Limestone-measures around Dalmellington was burnt and useless. In calculating on a thickness of only 10 feet of coal in the Limestone-measures at Patna, and of 6 feet in those

* *Trans. Inst. M.E.*, vol. xviii., page 394.

† *Ibid.*, vol. xviii., page 207.

‡ *Ibid.*, vol. xviii., page 395.

measures at Dalmellington, he (Mr. Dron) had made a considerable deduction for basalt-dykes and burnt coal.

The discussion was then closed, after a hearty vote of thanks had been awarded to Mr. Dron for his valuable paper.

DISCUSSION OF MR. WM. SMITH'S PAPER ON "HAULING AND PUMPING UNDERGROUND BY AN OIL-ENGINE."*

Mr. T. H. MOTTRAM said that he had seen the oil-engine and haulage-plant described by Mr. Wm. Smith, and it seemed to do its work efficiently. In 1889, he had read a paper on a pumping-plant, worked by an oil-engine at No. 5 pit, Rosehall collieries.† Since then, however, requirements had demanded a larger engine, and one of similar size to that described by Mr. Smith had been erected and was being utilized for pumping, hauling and lighting. The new Tangye engine, of 8 brake-horsepower, was fitted with two fly-wheels for electric driving and running at 200 revolutions per minute. The quantity of oil used (Oakbank of 0·725 specific gravity) was 8 gallons per day of 10 hours, and the price was 9d. per gallon. In addition to driving the electric haulage-plant and to pumping from an inside dook, the engine drove a three-throw Warner pump, and forced the water to the pit-bottom against a head of 70 feet; and it was pumping by means of a tail-rope from another dook. The engine and motor-rooms were also lighted by the plant. The total cost of installation was £500, very little more than the cost of the haulage and pumping-plant described by Mr. Smith. He (Mr. Mottram) was pleased to notice that Mr. Smith in his paper had appended the rules framed for the guidance of the enginemen and others. It was very important that no inflammable material should be used in the construction of underground engines, and also that the exhaust gases should be carried direct into the return air-course and then to the upcast-shaft, without passing through any of the working-places. These conditions, he noticed, prevailed at Jellieston colliery.

The discussion was then closed, a hearty vote of thanks being given to Mr. Smith for his interesting paper.

* *Trans. Inst. M.E.*, vol. xviii., page 396; and vol. xix., page 58.

† *Trans. M. Inst. Scotland*, vol. xi., page 109.

DISCUSSION OF MR. H. M. CADELL'S PAPER ON "AN INDIAN COLLIERY AND ITS MINERS."*

Mr. James Barrowman thought that the paper was of great interest because it described the social condition of the miners. This, in almost every respect, was similar to that which existed in Scotland for 200 or 300 years before the beginning of this century. There were the miner, his wife, and children going down the pit in the morning, the man hewing, and the wife and children carrying coal to the shaft. They now considered that this was an unsuitable occupation for women and children; but it was suitable in the early times of the coal-industry, and under the conditions which then prevailed. Similarly it might be desirable in India at the present time, but when the pressure of trade became greater and the use of machinery became more general this state of affairs would be relegated to the past, as it had been in this country. So long, however, as the habits and customs of the people remained in a primitive condition, these methods might continue in India, but it would ultimately come to an end and probably much more quickly than it had done in Scotland.

The further discussion of this paper was adjourned.

REPORT OF THE DELEGATE TO THE CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, BRADFORD, SEPTEMBER, 1900.

By JAMES BARROWMAN.

In accordance with the practice of former years, there were two meetings of the Conference, one on the first day, and the second on the last day of the meetings of the British Association for the Advancement of Science.

The object of these meetings of the Conference is to interest the various Societies, represented by the delegates present, in some common subject of scientific investigation, which, if undertaken in this joint manner, will yield larger results than if left to individual pursuit.

There has been a feeling among the delegates, gaining strength of late years, that the proceedings of the Conference require improvement, as the subjects usually submitted are of too restricted a nature to interest the Conference as a whole.

* *Trans. Inst. M.E.*, 1900, vol. xix., page 60.

Following upon a discussion at the meeting at Dover in 1899, the Corresponding Societies Committee invited delegates to forward to the Committee their views as to the best ways of making the Conferences more useful. A number of suggestions were sent in, among others the following by the Yorkshire Naturalists' Union, and these were submitted as resolutions to the first meeting of the Conference at Bradford :—

1.—It is desirable that the Conference of Delegates be allowed to meet on the first day of the British Association Meeting, and make their own arrangements for subsequent meetings and order of business.

2.—It is further desirable, in order to make the discussions of the Conference of Delegates more useful to the local societies, that they should have some choice in deciding the subjects for discussion at the meetings of the Conference, and it is suggested that a circular be sent every year to each of the Corresponding Societies asking them to send to the Committee a list of subjects for discussion (not more than two or three) at the forthcoming meetings. The Committee will then send to the Corresponding Societies a schedule containing the titles of all the subjects proposed for discussion, asking the society to mark such of these subjects as it deems most desirable to discuss at the conference meeting. On receipt of this information, the Committee shall arrange the list of subjects in order of precedence, as indicated by the support allotted to each subject, and a copy of this list shall be sent as an agenda-paper to each of the Delegates and Corresponding Societies before the first meeting of the delegates.

As delegate from this Institute, I supported the resolutions, as they were quite on the lines of my own written suggestions. The Chairman of the Conference, however, did not formally put the resolutions to the meeting, being apparently satisfied with the expression of opinion elicited in the discussion, and it may be expected that the course indicated in the second resolution will in future be taken to introduce subjects of more general interest.

A resolution was submitted and carried unanimously, requesting the Council of the British Association for the Advancement of Science to take steps for the securing to each Corresponding Society copyright in its own Transactions. It appears that copyright does not exist, at present, unless the society makes a payment to the author of each paper. It was found at the close of the meetings of the British Association that this resolution had not been sent to the proper authority, probably because the British Association disclaims all copyright in its proceedings.

At the second meeting of the Conference, the subject of "Dew Ponds" was submitted for discussion. Dew ponds are ponds on the top of eminences on the Chalk Downs of Southern England which, while artificially made and filled with water at first, have no after source of supply beyond rain, mist, and dew, and yet serve to water flocks of cattle and sheep without becoming dry. The subject, while interesting, was too local in character to claim the attention of the Conference as a whole, and illustrated what has already been stated as to the need of subjects of wider scope.

At the second meeting of the Conference, a representative from each of the sections of the British Association submitted recommendations as to lines of investigation in which the Societies might proceed within the limits of the several sections into which the Association is divided. A recommendation was submitted from the Geological Section for greater interest to be taken in the collection of photographs of geological interest and in reporting the occurrence of erratic boulders. Scotland is poorly represented by photographs in the collection of the

British Association, and this is a direction in which members of this Institute who use the camera could work with good results.

Of the papers read before the British Association, there was an unusually large proportion bearing, more or less, directly upon mining.

In the Geological Section, Prof. Sollas' presidential address dealt with speculations as to the age of the earth's solid crust; while Prof. J. Milne's report on the great earthquakes recorded in 1899, emphasized the need of a more thorough investigation of earth-movements and the conditions of underground-temperature and gas-accumulation.

A joint discussion between the Geological and Botanical Sections on "The Conditions during the Growth of the Forests of the Coal-measures," gave opportunity for rival theorists to express their views; but there still remains much to be said on both sides.

In the Mechanical Section, an important paper was read by Mr. J. G. H. Glass on "The Coal-fields and Iron-ore Deposits of the Provinces of Shansi and Honan, and Proposed Railway Construction in China." The author estimated that these provinces contain coal of good quality sufficient to maintain an output equal to the present output of the United Kingdom for 3,000 years, and stated that cast-iron could be made on the spot for about 12s. a ton. The present primitive system of carriage on donkeys costs from 2½d. to 5d. per ton per mile, and before these mineral-fields can be developed, a railway to the coast of 500 miles in length is required.

Other papers related to "Power Production: Comparative Cost of the Steam-engine, Water-turbine, and Gas-engine"; "A Concealed Coal-field beneath the London Basin"; "Rapid Changes in the Thickness and Character of the Coal-measures of North Staffordshire," etc.

At an evening lecture to artizans upon Electricity, Prof. Silvanus Thomson referred to the waste of coal in the running of small engines with shafting and belting, and strongly advocated the establishment of large power-centres at the pit-mouth, where gas should be produced from the coal to actuate gas-engines, by which electricity would be generated, to be distributed in all directions cheaper than could be done by the water-power of Niagara.

Mr. D. BURNS read the following paper on "Weight of Winding-drums for Deep Shafts":—

WEIGHT OF WINDING-DRUMS FOR DEEP SHAFTS.

By DANIEL BURNS.

In winding from deep shafts, the weight of the winding-rope becomes an important factor, and several methods are in use to eliminate it. The least complicated of these methods is to compensate the weight of the rope by means of a spiral drum—the only objection to the use of such a drum being its necessarily large diameter and consequently heavy weight. The writer proposes, in this paper, to deal with the mechanics of the question, so far as it applies to the weight of the winding-drum.

When a run has to be accomplished within a given time, a certain amount of work has to be expended, in order to create a sufficient angular velocity of the drum, and if we consider this angular velocity to be the same in two cases, where only the weights of the drums differ, the work expended will vary as the weights.

Should the quantity of motion or momentum thus communicated to the drum be utilized in doing useful work at the end of the run, and after the steam has been shut off from the engine, there is no loss, if we neglect that due to friction, and the weight of the drum is of no importance, so far as economy of winding is concerned.

Should it, however, become necessary to maintain the speed of winding to near the end of the run, in order to complete the run within a given time, and the necessity arises for the application of the brake, or other means of helping the load to arrest the momentum of the drum within the proper distance, then a certain amount of the work expended at the commencement of the run is destroyed or dissipated in another form. Under these circumstances, the drum employed is too heavy, and ought to be made of lighter build, in order to obtain the most economical results.

A more exact interpretation of the foregoing statements will be obtained if we assume a possible case, where similar conditions exist in everything but the weights of the respective drums.

Let us then assume the following conditions to hold:—Depth of shaft, 300 fathoms; maximum speed of winding, 60 feet per second; useful load in each case, 4 tons; weight of the one drum, 60 tons; and weight of the other drum, 45 tons. Let g be the acceleration due to the force of gravity, or 32·2 feet per second per second; t, the time in seconds; v, the velocity in feet per second; W, the weight of moving mass (in this case the drums) in tons; l, the useful load in tons; a, the acceleration; and F, the force producing acceleration or retardation.

Then from the laws of motion, we have

$$\frac{\text{Gravity}}{\text{Acceleration}} = \frac{\text{Weight}}{\text{Force}}; \text{ or } \frac{g}{a} = \frac{W}{F} \quad . \quad . \quad . \quad . \quad (1)$$

but the acceleration is the velocity divided by the time, $\frac{v}{t}$; and if we substitute this value in the equation (1), we obtain the following equations:—

$$tFg = Wv; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\text{and, therefore } t = \frac{Wv}{Fg}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

And this equation gives the time taken to accelerate or retard the load W, if friction be neglected.

Going back to the drums, the time which the useful load will take to arrest the momentum is expressed by the formula (3), and with l substituted for F, it now appears as follows:—

$$t = \frac{Wv}{gl}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Substituting the numerical values in the equation (4), we arrive at the time of acceleration, and retardation, thus:—

First case, drum weighing 60 tons:—

$$t = \frac{60 \times 60}{32{\cdot}2 \times 4} = 27{\cdot}95 \text{ seconds.}$$

Second case, drum weighing 45 tons:—

$$t = \frac{45 \times 60}{32{\cdot}2 \times 4} = 20{\cdot}96 \text{ seconds.}$$

As we are considering the winding-engines to be of equal power in each case, we can now easily arrive at the shortest time required per run in order to obtain the maximum economy. Since the engines start from rest, and after a given time t, acquire

a velocity of winding equal to 60 feet per second, the average speed up to that point will be 30 feet per second; and, assuming uniform acceleration, the net results, in each case, may be tabulated as follows:—

First case, drum weighing 60 tons:—

	Time in Seconds.		Distance Load moves in Feet.
Acceleration	27·95	... ...	838·5
Retardation	27·95	... ...	838 5
Full speed	2·05	... ...	123 0
Total time ...	57·95	Total distance...	1,800·0

Second case, drum weighing 45 tons:—

	Time in Seconds.		Distance Load moves in Feet.
Acceleration	20·96	... ...	628·8
Retardation	20·96	... ...	628·8
Full speed	9·04	... ...	542·4
Total time ..	50·96	Total distance...	1,800·0

In the second example there is a gain of 7 seconds per run with the same expenditure of power, or to put it otherwise the winding-engine with the lighter drum will under similar working conditions draw 100 tons at the same cost as it would draw 88 tons, if fitted with the heavier drum; or, in other words, a saving of 12 per cent. is effected in this particular case by adopting a suitable drum.

Let us take a step further, and suppose that the brake is applied in the first case so as to stop the heavier drum in 20·96 seconds,—the time of retardation in the second case—then we have:—

	Time in Seconds.		Distance Load moves in Feet.
Acceleration	27 95	... ...	838·5
Retardation	20·96	... ...	628·8
Full speed	5·54	... ...	332 7
Total time ...	54·45	Total distance...	1,800 0

There still remains a loss of (54·45 – 50·96) 3·49 seconds in each run, in addition to the work converted into heat at the brake-blocks.

If a winding-engine of sufficient size be erected, the necessary velocity may be imparted to the heavier drum in the shorter time, but there will then arise the question of higher first cost, as well as extra expenditure of power.

In the foregoing statements, no account has been taken of

friction, but friction is proportional to the pressure between the surfaces in contact, other conditions being the same, so that here again the lighter drum has the advantage.

It becomes evident, if economical winding is desired, that the weight of the winding-drum is an important matter where rapid winding is necessary, and every care should be taken to keep it as low as possible.

Engineers are well aware of the trouble in working a winding-

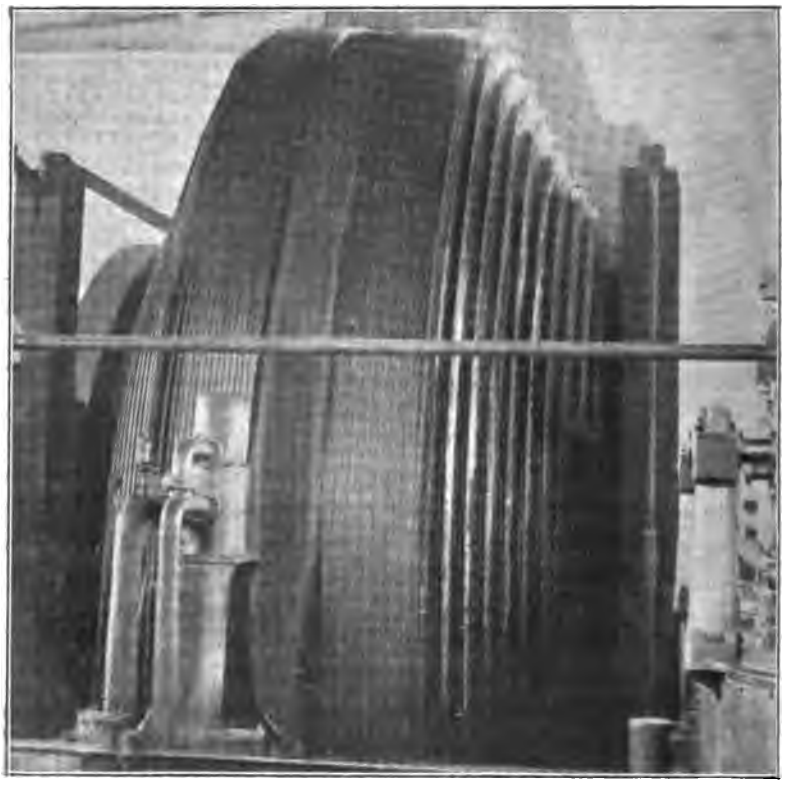


FIG. 1.—WINDING-DRUM AT DOWLAIS COLLIERY.

engine should the drum be too light, but if we remember that the case under consideration deals with conical drums and deep shafts we see that there is little possibility of trouble from this source, as the drum, even although designed to give the maximum strength with the minimum weight of material, will in no case be what could be termed a light drum.

When such a drum has to be designed, it ought to be the aim of the draughtsman to reduce its weight to the least possible amount consistent with safety, as this tends to keep down its first cost, and effects a constant saving in its afterworking.

Without going into the question of design, the writer attaches two illustrations of spiral drums, both of large size and great weight, and it will be seen that there is a great difference in the construction of these drums.

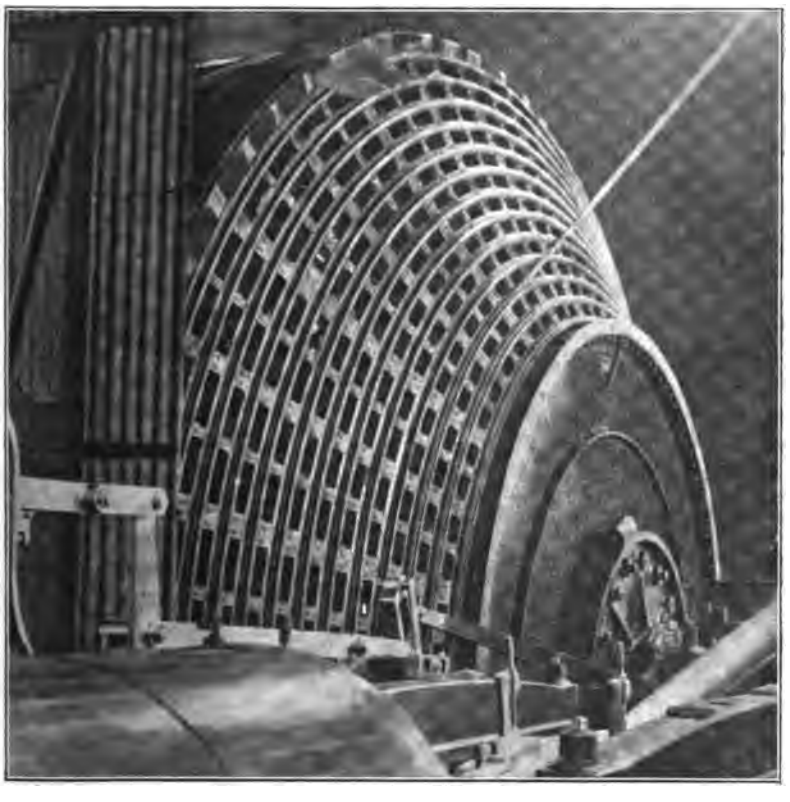


FIG. 2.—WINDING-DRUM AT LADY WINDSOR COLLIERY.

Fig. 1 shows the winding-drum at Dowlais colliery, Abercynon. It is 17½ feet in minimum and 33 feet in maximum diameter, built of cast-iron and heavy rolled plates, and fitted with an angle-iron scroll, which makes 10 turns round the conical part of the drum: the remainder of the necessary turns of the winding-rope being wound upon the cylindrical part of the drum.

Fig. 2 shows the winding-drum at Lady Windsor colliery, of the Ocean Coal Company, South Wales. It has a minimum diameter of 19 feet and a maximum of 35 feet; it is almost entirely constructed of mild steel, of an openwork structure, which greatly reduces its weight. This, in the opinion of the writer, is the proper principle underlying the construction of all such drums, where rapid winding from deep shafts has to be undertaken.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE ANGEL HOTEL, CHESTERFIELD, SEPTEMBER 1ST, 1900.

MR. MAURICE DEACON, PRESIDENT, IN THE CHAIR.

Mr. GEO. LEWIS (Derby) moved a cordial vote of thanks to Mr. M. Deacon, and the Sheepbridge Coal and Iron Company, Limited, for their hospitality and for the ready kindness with which the Langwith and Glapwell collieries had been thrown open to the inspection of the members.

Mr. A. H. STOKES seconded the motion, which was cordially approved.

The SECRETARY announced the election of the following gentlemen:—

MEMBERS—

Mr. A. B. EMMERSON, Colliery Manager, Ellistown Collieries, near Leicester.
Mr. F. M. BROWN, Colliery Manager, Stanley, Derby.
Mr. B. MADEW, Colliery Manager, Hillside, Pinxton, near Alfreton.

ASSOCIATE—

Mr. WILLIAM OAKLEY, Under-manager, Parliament Street, Newhall, Burton-upon-Trent.

STUDENT—

Mr. F. N. ILIFFE, Haunchwood Collieries, Nuneaton.

The Annual Report of the Council was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1899-1900.

The following is the usual comparative summary of the number of members and the state of the finances for the last three years:—

	Year 1897-98.	Year 1898-99.	Year 1899-1900.
Honorary Members ...	14	14	14
Life Members	9	9	8
Members	234	235	237
Associate Members ...	4	5	5
Associates	66	61	59
Students	32	32	28
Totals	359	356	351

	£ s. d.	£ s. d.	£ s. d.
Cash Receipts	458 3 5	476 2 6	493 17 6
Cash Payments ...	515 8 9	499 6 2	425 1 7
Bank Balance ...	28 5 11	5 2 3	73 18 2
Invested Fund ...	533 6 8	533 6 8	640 0 0
Totals	£561 12 7	£538 8 11	£713 18 2

Arrears considered recoverable at end of year	1897-98.	1898-99	1899-1900.
	£72 13 6	£66 4 6	£107 3 6

The following table shows the alterations in membership of the various classes during the past twelve months. The result is that the total is practically the same as last year, but the Council would be glad to see a substantial increase in the number of members, which can only be brought about by the efforts of individual members:—

		Less			Add		
	1898-1899.	Dead.	Resigned.	Transfd.	Elected.	Transfd.	1899-1900.
Hon. Members	14	—	—	—	—	—	14
Life Members	9	1	—	—	—	—	8
Members ...	235	4	9	—	13	2	237
Associate Members	5	—	—	—	—	—	5
Associates ...	61	—	7	—	4	1	59
Students ...	32	1	1	3	1	—	28
	356						351

The members who have died are as follows:—Messrs. John Jackson, Chesterfield; Henry Lewis, Annesley; R. Smallman, Nuneaton; I. W. H. White, Leeds; T. W. Jeffcock, Sheffield; and W. J. Lodge, Hucknall.

The Council are pleased to report so marked an improvement in the financial position of the Institution as is shown in the balance-sheet for the year just ended. For the past few years the loss on the working of the Institution had given the successive councils some anxiety, which has now been removed owing to the

economies which have been effected and to the increased number of subscriptions.

The annual meeting of The Institution of Mining Engineers was held at Sheffield in September last, and a general meeting took place in London in June.

Local meetings were held at Nottingham, in August, 1899, and an excursion meeting in April, 1900, in the neighbourhood of Nuneaton. The Council hope to arrange a joint meeting with the Midland Institute of Mining, Civil and Mechanical Engineers later on in the year.

The following papers have been contributed to the *Transactions* by members of this Institution since the last report of the Council:—

"The Educational and Social Condition of Colliery-officials and Workmen." By Mr. M. Deacon.
"Coal-cutting Machinery." By Mr. Henry Davis.
"The Hepplewhite Pit-props and Bars." By Mr. W. H. Hepplewhite.
"Preventible Colliery Fatalities." By Mr. B. McLaren.
"Underground Haulage at Glapwell Colliery." By Mr. J. F. Lee.

Mr. Edward Eastwood, Treasurer of the Institution, having expressed a wish to resign the post, the Council have accepted his resignation. They wish, however, to place upon record their appreciation of the many services which he has rendered to the Institution, and to express to him the thanks of all the members for the time and trouble that he has always placed at their disposal during very many years.

The Council have for some time past been of opinion that the location of the library at the Stephenson Memorial Hall, Chesterfield, was by no means adapted to the needs and use of the members. They have consequently arranged with the Free Library Committee of the Nottingham City Council to place their books in the University College, Nottingham, where they will be under the care of the City Librarian. The transfer has already taken place, but final arrangements have not yet been made, and particulars will be issued shortly to the members giving them information as to the contents of the library, and the conditions upon which books may be obtained.

The Council have further considered the question of the change of name of this Institution to "The Midland Counties Institution of Engineers." They have decided to recommend the members to adopt this title, and the question will be brought up for discussion at the Annual General Meeting.

Abstract of Accounts for Year ending July 31st, 1900.

Receipts.

	£ s. d.	£ s. d.
189 Members at £1 11s. 6d.	297 13 6	
1 Member transferred from Associate ...	1 11 6	
4 Associate Members	6 6 0	
64 Associates and Students	64 0 0	
		369 11 0
13 New Members and Entrance Fees ...	34 2 6	
5 New Associates and Students	5 0 0	
1 Entrance Fee from Associate to Member	0 10 6	
		39 13 0
2 Members re-joined		3 3 0
1 Member paid in error		1 11 6
Subscriptions paid in advance		9 7 0
Arrear Subscriptions received		34 17 0
Allowed on Cheque-book returned		0 1 0
Fire Insurance Premium returned		0 9 10
Midland Railway Company, Debenture Interest ...		15 8 0
Sale of Bookcase at Chesterfield		17 10 0
Bank Interest...		2 6 2
Balance brought forward		5 2 3
		£498 19 9

Examined and found correct, August 27th, 1900.

JOHN HALL,
JOHNSON PEARSON, } Auditors.

Expenditure.

	£ s. d.	£ s. d.
The Institution of Mining Engineers:—		
Calls 1899-1900,—Vols. xviii. & xix. ...	266 0 0	
,, 1898-1899,—Vols. xvi. & xvii. ...	10 9 0	
Transactions supplied upon payment of arrears	15 0 0	
		291 9 0
Exchanges, excerpts, etc.		4 17 11
Printing, etc.		29 8 10
Auditor		3 3 0
Reporting Proceedings		8 8 8
Postages, Parcels and Telegrams		10 5 8
Travelling and Incidental expenses		10 5 9
Fees at Meetings		1 3 0
Secretary's Salary		50 0 0
Removing Library		7 0 0
New Bookcase at Nottingham		6 5 0
Compiling Index of *Transactions*		0 10 0
Subscription returned, paid in error		1 11 6
Cheque-book		0 2 6
Banker's Commission		0 10 9
Balance in Bank :—to next account		73 18 2
		£498 19 9

The Treasurer in Account with Subscriptions, 1899-1900.

	£ s. d.	£ s. d.
239 Members as per List, 1899-1900, of whom 7 are Life Members		
232 Members at £1 11s. 6d.	365 8 0	
Less 1 paid in advance	1 11 6	
		363 16 6
2 Members paid in advance, 1900-1	3 3 0	
1 Member paid in advance, 2 years	3 3 0	
1 Member paid part in advan e ...	1 1 0	
2 Associates paid in advance ...	2 0 0	
		9 7 0
1 Member paid Entrance Fee		0 10 6
5 Associate Members, as per List		7 17 6
94 Associates and Students, as per List, and 1 Student is a Life Member		
93 Associates and Students at £1 ...	93 0 0	
Less 1 Student paid in advance ...	1 0 0	
		92 0 0
13 New Members and Entrance Fees		34 2 6
5 New Associates and Students		5 0 0
2 Members re-joined		3 3 0
		515 17 0
Arrears as per last Balance Sheet	67 16 0	
Add Arrears not in last Balance Sheet ...	14 9 0	
	82 5 0	
Deduct Irrecoverable...	34 7 6	
		47 17 6
		£563 14 6

Examined and found correct, August 27th, 1900.
John Hall, Johnson Pearson, } Auditors.

	Unpaid £ s. d.	Paid £ s. d.
189 Members at £1 11s. 6d....		297 13 6
1 Member transferred from Associate ... 7 Life Members		1 11 6
1 Member paid in advance		
41 Members unpaid	64 11 6	
232		
1 Member paid Entrance Fee from Associate		0 10 6
2 Members paid in advance, 1900-1		3 3 0
1 Member paid in advance, 2 years		3 3 0
1 Member paid part in advance ...		1 1 0
2 Associates paid in advance ...		2 0 0
4 Associate Members, paid		6 6 0
1 Associate Member, unpaid	1 11 6	
5		
64 Associates and Students, paid ...		64 0 0
1 Student paid in advance 1 Student is a Life Member		
28 Associates and Students, unpaid ...	28 0 0	
93		
13 New Members and Entrance Fees ...		34 2 6
2 Members re-joined		3 3 0
5 New Associates and Students ...		5 0 0
	94 3 0	421 14 0
Arrears as per last Balance Sheet	47 8 0	34 17 0
	141 11 0	
Deduct Irrecoverable	34 7 6	107 3 6
		£563 14 6

The PRESIDENT (Mr. M. Deacon) said the Council felt that the word "Chesterfield" was a cramped title for a body of engineers, extending over four large counties, and largely employed in the development of coal-mines. The Council thought it desirable that the name of the Institution should be altered to "The Midland Counties Institution of Engineers." He (Mr. Deacon) had pleasure in moving that the Report of the Council, together with the audited accounts of the past year, be adopted.

Mr. G. E. COKE, in seconding the motion, said that much credit was due to the secretary (Mr. G. A. Lewis), who had been most energetic in promoting the interests of the Institution.

Mr. JONATHAN PIGGFORD (Stanton Collieries) moved as an amendment, that the Report be adopted, with the exception of that paragraph relating to the change of name, and that the name of the Institution remain as at present.

Mr. J. BAGNOLD SMITH (Newstead) seconded Mr. Piggford's amendment.

After lengthy discussion, a vote was taken on the amendment, and 23 members voted for and 29 members against it. A vote was then taken on the motion, and 30 members voted for it, and 26 members against it. The minority was subsequently increased to 27, Mr. Lees (who was out of the room acting as scrutineer in the election of officers when the question was put) being allowed, with the permission of the meeting, to record his vote.

Mr. A. H. STOKES (H.M. Inspector of Mines) said that there was no provision for a poll in the rules, and the decision of the present meeting was final.

The PRESIDENT (Mr. M. Deacon) remarked that although he was quite clear as to the majority in favour of the alteration, he would take upon himself the responsibility of saying that the Council would re-consider that portion of their report, and that they would take a ballot of the members, in order that they might ascertain the wishes of those members who were not present that day.

Mr. A. H. STOKES said that the Council had accepted the resignation by Mr. Edward Eastwood of his office as Treasurer,

and had placed on record their appreciation of what he had done for the Institution. The members would be aware of the interest which Mr. Eastwood had always taken in the Institution, and the regular manner in which he had attended the meetings. Although Mr. Eastwood had seldom taken part in discussions, he had always had the interests of the Institution at heart, and for many years had filled to their entire satisfaction the office of Treasurer.

Mr. J. BAGNOLD SMITH said that the Institution was greatly indebted to Mr. Eastwood for his long and useful services as Treasurer.

Mr. A. B. MARKHAM (Stuffynwood) desired to express his cordial agreement with all that had been said respecting Mr. Eastwood, whose services, done in a quiet way, had been of great value to their Institution.

ELECTION OF OFFICERS FOR THE YEAR 1900-1901.

The SCRUTINEERS (Messrs. T. G. Lees and G. H. Davy), who received a vote of thanks for their services, reported the result of the ballot as follows:—

PRESIDENT:

Mr. MAURICE DEACON.

VICE-PRESIDENTS:

Mr. A. S. DOUGLAS.	Mr. W. B. M. JACKSON.
Mr. W. H. HEPPLEWHITE,	Mr. J. H. W. LAVERICK.
Mr. C. R. HEWITT.	Mr. W. WILDE.

COUNCILLORS:

Mr. G. H. ASHWIN.	Mr. C. LATHAM.
Mr. G. J. BINNS.	Mr. E. LINDLEY.
Mr. P. M. CHESTER.	Mr. W. NOWELL.
Mr. G. E. COKE.	Mr. W. G. PHILLIPS.
Mr. H. FISHER.	Mr. G. SPENCER.
Mr. H. R. HEWITT.	Mr. J. T. TODD.

The PRESIDENT (Mr. M. Deacon) said that he was very much obliged to the members for electing him President for a second year. He would like to allude to a few important points, which were vital to the successful carrying on of that Institution. One point was the prompt payment of subscriptions, as it was impossible

for their Institution to be successful unless its finances were in a sound condition. In view of the large development of the colliery industry in that district he considered that their membership should increase, instead of remaining in a stationary position. He hoped that each member would use his best endeavours to induce his friends, subordinates, and anyone over whom he had any influence to join their Institution. Further, a certain number of papers were read every year, but he did not think that they were representative of the power and capacity of their members. There was an ample field in every matter relating to mining for fresh ideas and fresh developments, and if every member would help to further the interests of their Institution by contributing to its *Transactions*, the value of the Institution would be materially increased.

Mr. A. B. MARKHAM had great pleasure in proposing a vote of thanks to Mr. M. Deacon for his services as President during the past year. He was associated with him in several undertakings, and there was no man in the country to-day of whom he had a higher opinion than Mr. Deacon as a mining engineer, and he believed that opinion was shared by the members.

Mr. J. BAGNOLD SMITH seconded the resolution, which was cordially adopted.

A paper by Mr. J. G. SHEARER on "Water-Softening Plant at Langwith Colliery" was taken as read as follows:—

WATER-SOFTENING PLANT AT LANGWITH COLLIERY.

By J. G. SHEARER.

It is not at every colliery that a supply of good water for boilers can be obtained, and where the quality is bad, it is desirable to adopt some method of treatment to deal with and neutralize the evil effects to the boilers caused by such water.

At Langwith colliery, near Mansfield, belonging to the Sheepbridge Coal and Iron Company, Limited, the water has 28 degrees of hardness (14·6 degrees being temporary and 13·4 degrees permanent), the solid matter weighing 29·2 grains per gallon. Previous to the introduction of the water-softening process, the scale formed in the boilers was of such a hard and flint-like character that it could not be chipped off the plates. The Galloway cross-tubes were nearly filled solid with deposit, so that a bar of iron 1 inch in diameter could not be pushed through some of them. The scale on the sides of the shells of the boilers and on the flue-tubes was in places 1½ inches thick, and the internal feed-pipes had to be taken off and the scale burned out of them every fourth or fifth week. The rivetted seams of the shells were constantly leaking, and it was of frequent occurrence that a Galloway tube had to be taken out and replaced, owing to fracture.

In 1897, a Howatson process water-softening plant was erected capable of dealing with 8,000 gallons of hard water per hour. The process reduces the hardness from 28 degrees to 8 degrees. The effect on the boilers is very marked: there is very little new scale forming, and the old scale is gradually breaking off in flakes. The newly deposited scale shells off, when about $\frac{1}{16}$ inch thick, in patches about 1 foot square; and it is found, by cutting grooves in the old thick scale down to the boiler-plate, that an action is set up by the softened water which lifts off the scale in patches in from 2 to 3 months.

Instead of the impurities in the softened water forming on the plates, they are thrown down in the form of mud or sludge and blown out through the blow-off cocks. In a new boiler, 8 feet in

diameter and 30 feet long, recently fixed, the quantity of sludge left in the boiler after working 4 weeks weighed 148 pounds, when dry. The tubes and shell were swept and no scale was found; and the plates were white as if lime-washed.

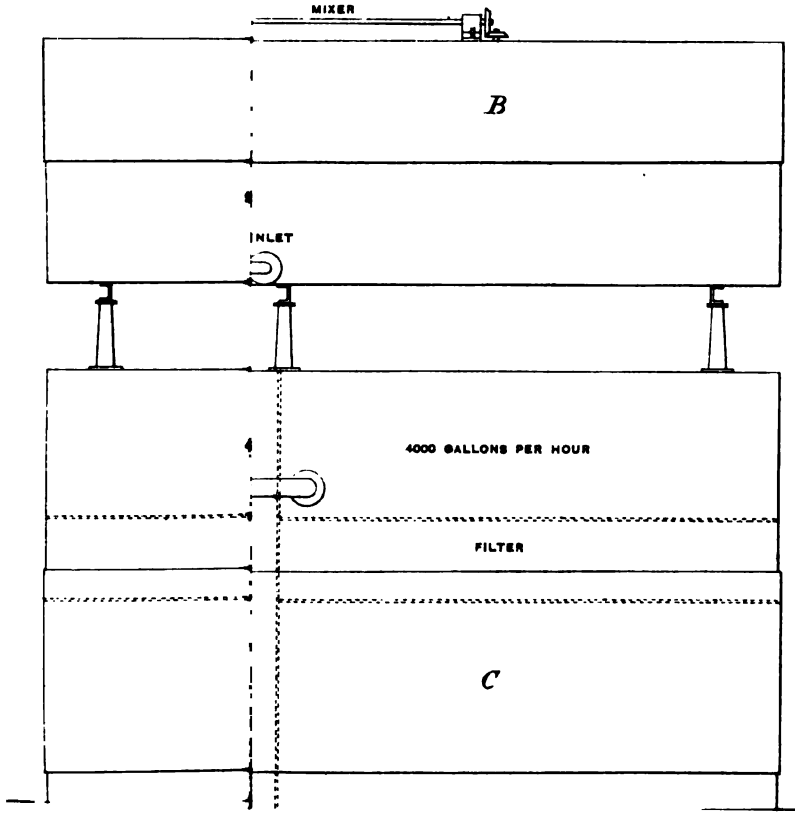
The plant (Figs. 1 and 2, Plate III.) comprizes a chemical or top-tank, *A*, with a capacity of 6,000 gallons, which is filled with water, and a charge consisting of 30 pounds of soda-ash (58 per cent. of alkali) and 80 pounds of Buxton lime. This is well mixed mechanically for 10 minutes and then allowed to settle for about 2½ hours. Whilst the water, in *A*, is settling, that in the other top-tank, *B*, is being run off. When the water in the tank, *A*, is ready, the outlet-valve, *b*, is closed and the outlet-valve, *c*, is opened. The chemically-treated water then runs into the small tanks, *a*, *a*. At the same time, the hard water is flowing into the small tanks, a_2, a_2, and mixing with the softened water in the small tanks, a_1, a_1. The respective quantities are regulated by float-valves, and by the orifices from the tanks, *a*, *a*, and a_2, a_2, being proportioned to give the required flow from each. From the tanks, a_1, a_1, the now softened water flows into the two filtering or bottom-tanks, *C*, *C*. These tanks have a partition in them from the top to within 2 feet of the bottom. The water passes down the side of the partition nearest the small tanks, *a*, and rises on the other side through a filter-bed, 2 feet thick, composed of wood-shavings between galvanized-iron netting, with a mesh about ¾ inch square. The water is then pumped by a pump to a storage-tank on the top of the engine-house, whence it is distributed to the boilers, in two ranges, and to the workmen's cottages.

It will be seen that only one top or chemical tank, *A* or *B*, is used at a time, and that both of the bottom or filtering-tanks, *C*, *C*, are continually at work. Four charges of chemicals are inserted per day, a charge every 3 hours, and the total quantity of water softened is 10,000 gallons per hour, of which 2,000 gallons passes through the chemical tanks, *A* and *B*, and 8,000 gallons passes through the hard-water tanks, a_2, a_2.

All the tanks are thoroughly cleaned once in 14 days. The spent-lime is used for making mortar.

A certain amount of trouble is caused by imperfect filtration. The water after being filtered holds in suspension a quantity of lime-particles, which, settling in the pipes and connexions, must be cleared out periodically. The effect is not so bad or so detrimental

Water-softening Plant &c.



in the cold-water pipes as in the hot-water feed-pipes, donkey-pump and connexions to boilers. The latter must be cleared out every 4 to 6 weeks. The deposit chiefly consists of lime, and is quite soft. In a 12 inches pipe, connecting two feed-water heaters, the thickness of the deposit around the pipe was 4 inches. This pipe had not been cleared for about 4 or 5 months, and in pipes leading from the feed-water heaters to the donkey-pump, 4 inches bore, the thickness of deposit attained $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in 5 or 6 weeks. It may be noted that the hotter the exhaust steam (or the greater the volume) coming into contact with the water, the greater is the amount of deposit.

Although the water after passing through the filter appears quite clear, or may have a slightly cloudy appearance, yet on coming into contact with heat the minute particles of lime unite, in the form of flat flakes, which do not settle so long as there is the slightest movement in the water, and it is this lime which fills up the pipes. It is also seen in the packings of the steam-cylinders, especially at the valve-spindles of the winding-engine. The valve-covers are sometimes quite white with lime.

To overcome these difficulties it is proposed to heat the water in the chemical and filtering tanks by means of hot water from the condenser attached to the hauling-engine. A quantity of water will be run into one of the filtering tanks; and, then, the contents of the chemical tank, after being heated and charged with chemicals, will be run into the bottom tank to make up $1\frac{1}{2}$ hours' water-supply. This water will be allowed to stand for $1\frac{1}{2}$ hours, and then it will be pumped to the feed-water heaters, where it will again come in contact with the hot exhaust-steam, and will also have time to settle, according to the volume of the feed-water heater. By this means it is hoped that very little deposit will be made either in the pump or in the connexions to the boilers.

The plant has been working for about $2\frac{1}{2}$ years, and is giving satisfaction. The softened water is used by the cottage-tenants, and is much preferred for household purposes.

One man attends to the water-softening plant, which occupies 4 to 5 hours per day, and works, with the cleaning-out of tanks, $13\frac{1}{2}$ to 14 shifts per month. The cost of softening 1,000 gallons of water, including chemicals and labour, is 0·8 penny.

The meeting was then closed.

GLAPWELL COLLIERY.

Two shafts, 900 feet deep, and 14 feet in diameter, are sunk to the Top Hard coal-seam. Coal is drawn from the downcast shaft on double-decked cages, with two 10 cwts. tubs on each deck, which are changed at separate levels simultaneously. The rope-conductors are 1½ inches in diameter, two ropes being placed on each side of each cage with a weight of 50 cwts. on each rope. Ormerod safety-hooks are used. The props and signals are worked by a banksman on the top deck, the man on the bottom deck signalling to the top level by means of a semaphore. The upcast shaft is at present being prepared for coal-drawing.

There are 12 Lancashire boilers, 28 feet long by 7 feet in diameter, 2 boilers 28 feet long by 8 feet in diameter, and one 30 feet long by 8½ feet in diameter; they are all hand-fired. The feed-water is heated to a temperature of 180° to 200° Fahr. by means of exhaust steam. The steam-pressure is 65 pounds per square inch.

The winding-engine at the downcast shaft has 2 horizontal cylinders, 36 inches in diameter by 6 feet stroke, and a parallel drum 16 feet in diameter by 9 feet wide.

The winding-engine at the upcast shaft has 2 horizontal cylinders 30 inches in diameter by 5½ feet stroke, and a conical drum, 12 to 14 feet in diameter.

A Waddle fan, 40 feet in diameter, is driven at 50 revolutions per minute by a single horizontal cylinder, 30 inches in diameter by 3 feet stroke. A King speed-recorder is used to record the number of revolutions per minute.

The endless-rope hauling-engines (on the surface) consist of a horizontal engine, with cylinders 26 inches in diameter by 3 feet stroke, geared 10 to 1, and a driving-wheel 9½ feet in diameter; and an horizontal engine, with a cylinder 26 inches in diameter by 3 feet stroke, geared 7½ to 1, and a driving-wheel 7 feet in diameter. These two hauling-engines work the main dip-haulages. An horizontal engine with 2 cylinders, 16 inches in diameter by 3 feet stroke, geared 8·8 to 1, and a driving-wheel 7 feet in diameter, works the level or Hardwick engine-plane on the south side of the colliery.

The air-compressing plant has 2 horizontal steam cylinders 30 inches in diameter by 5 feet stroke. The compressed air is used below ground for working the hauling-engines and several pumping-engines.

The coal is weighed separately on each deck, and is conveyed by creepers to two revolving-tipplers. After being tipped, it is elevated by two parallel cross-belts, 57 feet long by 6 feet broad, and then gravitates over fixed screens which separate the large coal from the smaller sorts—the latter are divided by a jigging-screen into steam hards, cobbles, nuts and slack. The nuts and slack are taken by a belt and elevated so as to fall over another jigging-screen, which throws the nuts on to a picking-belt, 47 feet long by 4 feet wide, and the slack into a creeper, which carries it into trucks or into another creeper, which conveys it to the fire-holes at the boilers as required. The hard coal picking-belt is 173 feet long by 4 feet broad, with a small screen at the end to take out the slack made after the first screening. The steam-hard belt is 185 feet long by 4 feet broad. The cobbles, nuts and slack are taken out by means of small screens at the belt-ends. Thirty men and boys are employed in picking and cleaning cannel on the main belts.

A Wheeler condenser is erected, and nearly ready to attach to the air-compressors and the two main hauling-engines.

Gas is manufactured at the colliery to light the surface, and is forced underground for use at the pit-bottom, shaft-sidings, and stables.

The Top Hard coal-seam is worked entirely on the long-wall system, and all the haulage is on the endless-rope system. The rope lies on the tubs on the main dip haulage-roads and the rope is below on the level haulage-roads.

LANGWITH COLLIERY.

The two shafts, each 14 feet in diameter, are 1,620 feet deep to the Top Hard coal-seam. Coal is drawn from the downcast shaft on three-decked cages, with two 10 cwts. tubs on each deck, which are changed simultaneously at separate levels. The rope-conductors are 1½ inches in diameter, 4 to each cage, with 90 cwts. load on each rope. King improved safety-hooks are used.

The upcast shaft is also used for drawing coal, and is fitted with double-decked cages, with two 10 cwts. tubs on each deck, which are changed simultaneously at separate levels. The rope-conductors are 1½ inches in diameter, 4 to each cage, with 73 cwts. load on each rope. Ormerod safety-hooks are used.

The props in both shafts are worked by the banksman on the top deck, and signals are arranged between the decks.

There are 2 Cornish boilers and 18 Lancashire boilers. The Cornish boilers are used for the pumping-engine supplying the colliery with water. Fifteen of the Lancashire boilers are 28 feet long by 7 feet in diameter; one is 28 feet long by 8 feet in diameter; and two are 30 feet long by 8 feet in diameter. The last-mentioned two boilers are fired mechanically, and are fitted with fuel-economizers and Hodgkinson automatic coking-stokers. The other boilers are all hand-fired. The working pressure of these boilers is 65 pounds per square inch. The whole of the boiler feed-water passes through a Howatson water-softener, and is heated by exhaust steam to a temperature of 198° Fahr.

The winding-engine at the downcast shaft is of vertical type, with 2 cylinders, 40 inches in diameter by 6 feet stroke, and a parallel drum, 20 feet in diameter by 9 inches wide. The winding-engine at the upcast shaft has 2 horizontal cylinders, 30 inches in diameter by 5 feet stroke, and a parallel drum, 14 feet 4 inches in diameter by 11½ feet wide.

The Guibal fan, 40 feet in diameter, is driven at an average speed of 48 revolutions per minute, by duplicate horizontal cylinders, 36 inches in diameter by 3 feet stroke.

There are two hauling-engines, fixed on the surface, and working on the endless-rope principle. One hauling-engine working through the downcast shaft, has 2 horizontal cylinders, 18 inches in diameter by 3 feet stroke, the gearing is 5¼ to 1, and the driving-wheel is 8 feet in diameter. The second hauling-engine working through the upcast shaft, has 2 horizontal cylinders, 18 inches in diameter by 3 feet stroke, the gearing is 5 to 1, and the driving-wheel is 7 feet in diameter.

The colliery is lighted by electricity, generated on the spot. A horizontal engine, with 2 cylinders, 12 inches in diameter by 18 inches stroke, works the dynamo, which has a capacity of 155 ampères at 110 volts when running at 840 revolutions per minute. This plant is now being superseded and increased by two horizontal engines, and two dynamos for extending the lighting to the colliery-village, and for power purposes. These engines each have 2 cylinders, 14 inches in diameter by 28 inches stroke, and the dynamos have each a capacity of 200 ampères at 200 volts, when running at 800 revolutions per minute.

The coal from both shafts is taken to the same screening-plant, and is passed over bar-screens. This plant is now being superseded by jigging-screens and picking-belts. The tubs from both shafts are taken by creepers to two Fowler automatic tipplers, taking 2 tubs in each at the same time. The empty tubs gravitate to the drawing shafts. The jigging-screens take out the slack, nuts and cobbles, and the coal passes on to a picking-belt, 155 feet long by 4½ feet wide, while the cobbles are conveyed to another picking-belt, 74 feet long by 3½ feet wide. Bright coal and picked hards are taken from the main picking-belt by means of lowering belt-shoots, and the steam hard coal passes over the end of the main picking-belt into trucks. Bright cobbles are also picked on the cobble-belt. Smaller belts and screens are arranged for the nuts and slack-coal.

The Top Hard coal-seam is being worked entirely on the long-wall system, and the haulage is on the endless-rope system.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, OCTOBER 22ND, 1900.

MR. J. C. CADMAN, RETIRING-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

ASSOCIATE—

Mr. JOHN WILLIAM SUMNALL, Assistant Manager, High Carr Colliery.

STUDENTS—

Mr. HOWELL HOPWOOD, Mining Student, Vron Colliery, Wrexham.

Mr. F H. WYNNE, Mining Student, Durham College of Science, Newcastle-upon-Tyne.

The Annual Report of the Council and of the Finance Committee were read as follows:—

ANNUAL REPORT OF THE COUNCIL.

During the year, 8 members, 5 associate members and 3 associates have been elected; and the name of the late secretary has been added to the list of honorary members.

Death has deprived the Institute of two very old members, namely, Mr. James Lucas and Mr. F. Sylvester. Mr. Lucas was elected president of the Institute in 1883, and Mr. Sylvester had served as vice-president and member of the council for many years.

The following table shows the membership during the past 5 years:—

Year ending.	Life Members.	Honorary Members.	Members.	Associate Members.	Associates.	Students.	Totals.
July 31st, 1896.	1	6	120	3	37	16	183
,, 1897.	1	6	116	5	36	19	183
,, 1898.	1	5	112	4	46	14	182
,, 1899.	1	5	106	5	43	13	173
,, 1900.	1	6	108	4	44	12	175

Last year, the names of three gentlemen appeared as honorary members and members, so that the actual number of members was 172.

In November, 1899, Mr. J. R. Haines resigned the position of secretary of the Institute, after having filled that position since the formation of the Institute, with the exception of a few years. In order to evince their appreciation of his long and valuable services, the members made him a presentation consisting of an illuminated address, silver-plate and jewellery.

During the year, general meetings were held in December, February, March, May and July, at which the following papers were read:—

"Presidential Address." By Mr. J. C. Cadman.
"Notes on the Kœpe System of Winding." By Messrs. John Gregory and J. T. Stobbs.
"A New Ventilating Fan." By Mr. Robert Oswald.
"The Howat Safety-Lamp and the Darrah-Patterson Igniter." By Mr. J. G. Patterson.

Various important papers have been under discussion during the year.

Excursion meetings were held:—In October, 1899, at Derby, where the works of Messrs. John Davis & Son, and the Haslam Foundry and Engineering Company, Limited, were open for inspection by the members. In November, 1899, at Smethwick, where the works of The New Conveyor Company, Limited, and the Smethwick Corporation Gasworks were inspected. In February, 1900, the Power-station of the Potteries Electric Traction Company, Limited, at Stoke-upon-Trent, was kindly thrown open for inspection. In July, 1900, at Blaenau Festiniog, the Llechwedd slate-quarries belonging to Messrs. Greaves & Sons were visited. The best thanks of the members are due to each of the firms whose works were inspected, for their kind reception and hospitality.

The Council again wish to impress on the members how desirable it is, and indeed necessary, if the Institute is to be carried on successfully, that they should take a more energetic interest in its affairs, (1) by attending the meetings and taking part in the discussions; (2) by reading papers or calling attention to matters of interest; and (3) by increasing the membership. It is probably within the power of most members to contribute to the prosperity of the Institute in one or more of these ways, and the Council trust that all will endeavour to do so.

The Council wish to acquaint the members that arrangements

have been made for holding the meetings at the Grand Hotel, Hanley. There a room has been secured in which to place the library belonging to the Institute, where members may go on the production of their membership ticket at any time, consult any books, and obtain the loan of them after they have been catalogued and arranged by Mr. J. T. Stobbs, who has kindly consented to act as librarian.

ANNUAL REPORT OF THE FINANCE COMMITTEE.

The Finance Committee herewith submit their statement of accounts for the year ending July 31st, 1900. The total receipts amounted to £239 10s. 6d., of which £154 1s. 0d., was paid by members for the current year's subscriptions, leaving a balance of £109 3s. 6d. unpaid to July 31st last.

Of the balance of arrears left over from last year £83 4s. 6d., has been paid, leaving £45 4s. 5d. unpaid, and making a total of £154 7s. 11d. of arrears still outstanding.

The expenditure for the year has exceeded the gross income by £9 13s. 10d. Printing and stationery are nearly £12 more than last year, caused chiefly by the change in the secretary's address, etc.: this charge will be considerably reduced next year.

The Finance Committee hope to complete arrangements which will further reduce expenses.

Of the payments made to The Institution of Mining Engineers, £7 12s. 0d. belongs to last year's accounts, but owing to the dates on which the accounts are rendered it appears in this year's accounts.

The Finance Committee especially desire to direct the attention of members to the amount of outstanding arrears, and despite the special appeal made last year, this amount has increased by £21. With the increase in membership since July 31st last, the Institute will prosper financially, provided the subscriptions are paid promptly, and the amount of arrears now outstanding is remitted to the Treasurer.

Mr. W. STATHAM moved the adoption of the reports.

Mr H. R. MAKEPEACE seconded the resolution, which was carried unanimously.

Mr. W. GIBSON read the following paper on "The Upper Coal-measures" etc.:—

THE UPPER COAL-MEASURES SURROUNDING THE MARGINS OF THE NORTH STAFFORDSHIRE COAL-FIELD, AND THEIR BEARING ON THE EXTENSION OF THE COAL-FIELD TO THE WEST.

By WALCOT GIBSON, F.G.S.

Communicated by permission of the Director-General of H.M. Geological Survey.

The productive measures of the Pottery coal-field are surrounded on the south and west by a great thickness of red marls and red and grey sandstones, containing thin seams of coal but none of commercial value. Previous to the re-survey of the coal-field by the officers of the Geological Survey these strata had received little attention, though it had been recognized that the chief coals and ironstones underlay them on the south; and under this impression the shafts of the Great Fenton and Florence collieries were successfully sunk to the productive measures.

While engaged in remapping the coal-field for the Geological Survey, Mr. C. B. Wedd and the writer paid special attention to these upper strata, and they were of opinion that on the west of the coal-field, as on the south, the productive measures lie within workable depths beneath the upper strata which occur at the surface in the Audley district.

The writer proposes in this paper to deal with the chief characters of these upper strata, their distribution round the margins of the coal-field, and the light which they throw on the future extension of the coal-field to the west.

The strata of Coal-measure age in North Staffordshire are of exceptional thickness, being about 7,000 feet from the first grit to the highest bed exposed; and the upper barren strata form nearly one-third of the total thickness.

In no other district in England are these higher measures so well exposed in numerous natural and artificial sections. The complete sequence is exhibited again and again, while the variation in lithological characters of the subdivisions is so extremely small that the following groups, in descending order, can be recognized without difficulty throughout the district:—

Upper Coal-measures—	Feet.
4. Keele Series	+ 700
3. Newcastle-under-Lyme Series ...	300
2. Etruria Marl Series	800 to 1,100
1. Black Band Series	300 to 450

The importance of ascertaining the thickness of these subdivisions and the characters by which they can be recognized is obvious, for as Prof. Hull and the late Sir Warington Smyth have pointed out, their great thickness will be the chief obstacle presented to the miner in future explorations around the margins of the coal-field.

(1) *The Black Band Series* consists of marls, clays, shales and grits, mostly of a grey colour, in which lie (chiefly in the lower portion) thin seams of coal, and the valuable bands of ironstone known as the Black Band, Half-yard, Red Shag, Red Mine and Bassey Mine. The base is drawn at the Bassey Mine coal and the summit a few feet above the Black Band ironstone of the Shelton district. The thickness near Etruria is 450 feet, which is probably the maximum thickness attained by this division anywhere in the district, the average being about 300 feet.

Towards the base, two or more thin bands of freshwater limestone are developed, containing fish-remains, *Anthracomya Phillipsii*, *Carbonia* and *Spirorbis*. The lowest of these bands, as pointed out by Mr. Ward, is markedly persistent throughout the district. Mr. Ward has traced its outcrop from Longton to Burslem, and the writer has extended its horizon northward to Tunstall. Throughout this long extent it never varies its position of 36 to 40 feet above the Bassey Mine coal.

At Sneyd Green, Cobridge and Burslem, some thin bands of fine grained, slightly calcareous grits, lying about 60 feet above the Bassey Mine, contain the curious little fossil described by Dr. Wheelton Hind, under the name of *Carbonicola Vinti*. Other thin bands of limestone and shale are met with higher up in the Black Band series, but they are impersistent. The Black Band ironstones contain numerous remains of *Anthracomya Phillipsii*.

The bands of fossiliferous limestone near the base, the Black Band ironstones, and the essentially grey colour of the measures serve to distinguish this subdivision.

(2) *The Etruria Marl Series* is almost entirely made up of red and mottled marls and clays, largely used in the manufacture of bricks, tiles, etc. The base is a greenish-yellow grit, on which the town of Longport is built. Bands of greenish grit, seldom more than 5 feet thick, but often very coarse and conglomeratic, occur at intervals throughout the series, and near the summit and base thin bands of impure limestone with *Spirorbis* and *Carbonia* are locally developed (Chesterton, Grange Farm, etc.). The thickness varies from 1,100 feet near Etruria to about 800 feet in the Silverdale district. It is in this series that the shafts of the Great Fenton and Florence collieries begin, but both start below the summit of the series.

The distinctive feature of the Etruria Marl series is the presence in it of thin bands of green and greenish-yellow grits lying in the midst of red and mottled marls. Occasionally, as at Chesterton, a few feet of fine-grained grey sandstone overlying a thin coal and ironstone may be developed, but as a whole red marls predominate.

(3) *The Newcastle-under-Lyme Series* consists of thick sandstones, shales and marls, all grey in colour, but with occasional mottled marls near the summit. Almost the entire sequence—300 feet—is exposed in the railway-cutting at Newcastle, where the four thin coals, which are generally present near the middle of the sequence, can be made out. At the base, one or two bands of freshwater limestone, about a foot thick and of a grey or red colour, are developed throughout the district and make an excellent datum-line. The limestones and shales immediately above contain *Carbonia*, *Spirorbis*, *Anthracomya calcifera*, fish-remains, and *Estheria tenella*. The grey colour, four thin coals in the middle, and the limestones at the base serve to distinguish this series from the Etruria Marls, while the greater development of sandstones separate it from the Black Band series.

(4) *The Keele Series* includes the red sandstones, marls and shales, which are developed on the south and west of the coal-field round Trentham, Barlaston, Keele and Madeley. These strata, from their deep red colour, were formerly grouped with the Permian. Mr. Wedd and the writer have found that they contain bands of limestone with *Carbonia*, *Spirorbis* and fish-remains,

developed at several horizons; while Mr. Benson informed the writer that a thin coal-seam was found in this series in making the racecourse at Keele Park. The series is also apparently conformable to the Newcastle-under-Lyme series: the supposed unconformity near Leycett being due to the wrong correlation of the strata there exposed.

The maximum thickness of the Upper Coal-measures, exclusive of the Keele series, is about 1,800 feet, and the writer thinks that they will nowhere be found to be less than 1,200 feet thick along the immediate borders of the coal-field. Of this thickness, the Etruria Marls contribute the chief portion. It is therefore important to trace their outcrop, and to determine their probable thickness in the different localities where they are developed. This has been done by Mr. Wedd and the writer.

The Trent between Hanford and Stoke, and the Fowlea brook between Stoke and Chatterley, follow the higher portion of the outcrop of these marls; they also occur at the surface, and form much of the ground round Longton and Great Fenton; the road between Trentham and Whitmore cuts through them, and they form the ground lying west of the Market Drayton road between Shutlanehead and Seabridge. The entire sequence is exposed in the neighbourhood of Chesterton.

The most interesting exposure lies west of the anticline between Audley and Hayes farm. Near Audley, Mr. Wedd finds the rocks cropping out between Audley town and Audley station, and from here the writer has traced them as far south as Craddock Moss farm, where they form the banks of the ravine extending west of the railway from Halmer-end to Leycett. It is this district to which the writer wishes to draw particular attention, but before doing so it is necessary to point out one of the laws governing the distribution of the Coal-measures within the coal-field, for we there find a clue that helps to determine the probable thickness of the measures in the unexplored district west of the anticline.

The Pottery coal-field is structurally divided into two regions. On the east, there is the marked basin extending from Longton to Biddulph. On the west, the strata form the wellknown saddle extending from Silverdale to Talke. This structural difference

in the two areas is accompanied by a great change in the thickness of the productive measures, including the Black Band series. The thickness at Shelton, between the Black Band ironstone and the Bulhurst coal-seam, is about 3,900 feet; while on the anticline only 2,400 feet of strata separate the Top Red mine and Bulhurst coal-seam. Supposing the seams in the two areas to be correctly identified, this makes a decrease of 1,500 feet of strata in a short distance. This decrease is remarkable, so much so that it seems impossible to escape the conclusion that the syncline and anticline represent areas more or less disconnected during the deposition of the measures.

The coincidence of maximum and minimum thickness of strata with a syncline and anticline respectively may be only accidental, but there is no doubt of the rapid attenuation westward of the productive measures. This attenuation is shared by the Etruria Marls which, as before mentioned, are 1,100 feet thick near Etruria and only 800 feet at Silverdale.

Taking the thickness at Silverdale to hold good east of Audley station and Halmer-end, we may calculate the depth to the Bulhurst coal-seam to be 3,200 feet. A considerable portion of the marls, however, crop out between Audley town and Audley station, so that a position could be selected where a shaft would reach the Bulhurst coal-seam at a much less depth.

In estimating how far the attenuation of the measures will extend westward, the writer thinks that the remarkable difference between the thicknesses at Shelton and Apedale must be taken into account. There is no doubt, as has often been stated, that the strata cropping out on the west of the Pottery coal-field represent the eastern margin of the great syncline of Coal-measures underlying the Cheshire plain, which connects the North Staffordshire coal-field with that of Denbighshire. It is known also that the Upper Coal-measures of the Denbighshire coal-field increase in thickness eastward in a remarkable manner. Taken in conjunction with the difference in thickness in the anticlinal and synclinal regions in the Pottery coal-field, it is not unlikely that west of Audley, as the syncline beneath the Cheshire plain is approached, the productive and Upper Coal-measures will also increase in thickness.

The sub-divisions of the Upper Coal-measures, so clearly defined in North Staffordshire, have been found by the writer to hold

good in the Nottingham and Denbighshire coal-fields. The Etruria Marls, especially, with the characteristic bands of greenish-coloured grits, are easily recognised in many borings and shafts, sunk through the Trias to the Coal-measures. The sequence of the Upper Coal-measures in North Staffordshire is therefore of more than local importance, and the writer thinks that the subdivisions will be an index to the horizon reached in future borings and shafts sunk in search of coal lying beneath the newer rock formations of the Midlands.

Mr. W. N. Atkinson (H.M. Inspector of Mines) observed that information bearing on the extension of the North Staffordshire coal-field southward and westward, was of great value; and the careful observations of Messrs. Gibson and Wedd, recorded in Mr. Gibson's paper, were likely to be of service in future explorations, in addition to their immediate value. He did not know anything more interesting in the North Staffordshire coal-field than this question of the extension of its boundaries, and they were very much indebted to Mr. Gibson for bringing the subject before the Institute in so clear and able a manner. The members had long been looking for the publication of the new series of the Geological Survey maps, and they must feel glad that there was a prospect that these would soon be obtainable.

Mr. J. Blaikie said he was glad to see this fresh evidence as to the extension of the coal-area of North Staffordshire. Messrs. Gibson and Wedd were going on sure grounds, and the information contained in Mr. Gibson's paper was a brilliant piece of work. He hoped before long that the members would see the western boundary tapped.

Mr. C. B. Wedd said that one of the most important points brought out in Mr. Gibson's paper was that the Keele series was directly conformable to the measures below. He endorsed all that Mr. Gibson had said in his paper.

The Chairman (Mr. J. C. Cadman) moved a vote of thanks to Mr. Gibson for his valuable paper, and expressed a hope that it would not be the last that he would read to the members.

Mr. Blaikie seconded the vote of thanks, which was carried.

ELECTION OF OFFICERS, 1900-1901.

The SCRUTINEERS reported the following appointments:—

PRESIDENT:
Mr. W. N. ATKINSON.

VICE-PRESIDENTS:
Mr. T. M. FAVELL. | Mr. A. M. HENSHAW. | Mr. G. A. MITCHESON.

COUNCIL:

Mr. W. G. COWLISHAW.	Mr. J. NEWTON.
Mr. G. H. GREATBACH.	Mr. F. RIGBY.
Mr. J. R. HAINES.	Mr. W. STATHAM.
Mr. JOHN HEATH.	Mr. J. T. STOBBS.
Mr. G. P. HYSLOP.	Mr. T. E. STOREY.
Mr. J. MADDOCK.	Mr. D. B. WOODWORTH.

TREASURER:
Mr. H. R. MAKEPEACE.

SECRETARY:
Mr. F. R. ATKINSON.

Mr. W. N. ATKINSON, on taking the chair, thanked the members for the honour which they had conferred upon him by electing him President of the Institute. He regarded the position as one of responsibility, as well as of honour, and he would do his best to promote the success of the Institute. He had great pleasure in proposing a vote of thanks to Mr. J. C. Cadman for his services as President during the past year.

Col. JOHN STRICK, C.B., in seconding the resolution, said that he had known Mr. Cadman to be assiduous in everything that he undertook to do.

The resolution was carried with applause.

The annual dinner of the members was held under the presidency of Mr. W. N. Atkinson.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN MASON UNIVERSITY COLLEGE, BIRMINGHAM,
OCTOBER 15TH, 1900.

MR. J. LINDOP, RETIRING-PRESIDENT, IN THE CHAIR.

The Minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentlemen were elected:—

MEMBERS—
Mr. FRANK H. THOMAS, Yieldfields Hall, Bloxwich.
Mr. JAMES F. THOMAS, Ferreira Gold-mine, Transvaal, South Africa.
Mr. ROBERT FELLOWS, Congraves Hall, Cradley Heath.

The Annual Report of the Council for the past year was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1899-1900.

The Council are again able to congratulate the members upon another year's successful work. The number of members of all classes upon the books at the end of the year was 176, an increase of 3 over the previous year. Two members (Messrs. Samuel Bailey and J. H. Cooksey) have died, 3 have resigned, 2 have been struck off the list, and 10 members have been elected.

The balance in the Bank on July 31st, 1900, was £312 12s. 11d. The receipts have been £179 16s. 4d., and the expenditure £173 10s. 0d., leaving a credit-balance of £6 6s. 4d. A donation of £52 10s. 0d. has been made to the Birmingham University Fund. The amount due for arrears of subscriptions, £153 4s. 0d., is larger than on any previous occasion. Although trade has been good, it has been very difficult to obtain the subscriptions from some of the members.

Four general meetings have been held, an interesting excursion was made to the Shireoaks collieries and the "Dukeries," and the Council have held 5 meetings.

The following papers have been read during the past year:—

"The Physical Conditions of the Mine upon the Re-opening of the Hamstead Colliery after the Fire." By Mr. F. G. Meachem.
"The Witwatersrand Gold-fields." By Mr. Francis Olds.
"The Rating of Coal-mines." By Mr. Alexander Smith.

The interests of the Institute would be considerably enhanced if more papers were read at General Meetings.

The Institution of Mining Engineers annually awards prizes of books, and one has just been awarded to Dr. J. S. Haldane and Mr. F. G. Meachem for their excellent "Observations on the Relation of Underground Temperatures and Spontaneous Fires in the Coal to Oxidation and to the Causes which favour it," read before this Institute.

Your thanks are again due and are hereby tendered to the authorities of the Birmingham University for the use of rooms for meetings. The members will be gratified to learn that it is intended to found a mining chair, in connexion with the University, but before developing the scheme, which is to be comprehensive in character, an advisory committee consisting of leading mining engineers will be formed, to confer with the College authorities.

The Institution of Mining Engineers, of which this Institute forms a part, continues to flourish and consists of 2,486 members. It has held two General Meetings during the year, one in South Yorkshire and the other in London; and 61 papers and other items of interest to mining engineers have been published in the *Transactions*.

A Benevolent Fund has been initiated on the lines of that established by the Institution of Civil Engineers in 1864, which has done excellent work, and the members will be individually requested to assist in this good cause.

Mr. R. S. WILLIAMSON moved the adoption of the report.

Mr. W. J. HAYWARD, seconded the resolution, which was adopted.

Dr. THE TREASURER IN ACCOUNT WITH THE SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS, FOR THE YEAR ENDING JULY 31ST, 1900. **Cr.**

	£	s.	d.		£	s.	d.
To Balance in Bank	358	16	7	By The Institution of Mining Engineers:			
,, Subscriptions received	174	1	0	Balance of Call for 1898-99 ... ... 19 19 0			
,, Bank Interest	5	15	4	Exchanges, etc. 11 13 4			
				Excerpt *Transactions*, etc. 0 19 2			
				Reducing Plates 0 10 0			
				Call for 1899-1900, on account 57 0 0			
					90	1	6
				,, Secretary's and Reporter's Salaries	50	0	0
				,, Rent, Rates, Cleaning, etc., of Institute Room	20	0	0
				,, Expenses of attending Meetings...	2	19	6
				,, Expenses of Audit	0	17	6
				,, Printing Circulars, Lists of Members, etc.	5	4	0
				,, Stamps, Telegrams, etc.	4	7	6
				,, Donation to Birmingham University	52	10	0
				,, Balance in Bank	312	12	11
	£538	12	11		£538	12	11

BALANCE-SHEET, 1899-1900.

Liabilities.	£	s.	d.	**Assets.**	£	s.	d.
To The Institution of Mining Engineers	41	16	8	By Subscriptions due	145	6	6
,, Balance	416	2	9	,, Balance in Bank	312	12	11
	£457	19	5		£457	19	5

Examined and found correct,

October 15th, 1900. DANIEL ROGERS, W. H. WHITEHOUSE, *Auditors.*

This balance is exclusive of considerably more than £100 worth of property, for which no credit is taken.

The Report of the Auditors and the Accounts were also received and approved.

ELECTION OF OFFICERS FOR THE YEAR 1900-1901.

The SCRUTINEERS reported that the following officers had been elected for the ensuing year:—

PRESIDENT: Mr. F. G. MEACHEM.

VICE-PRESIDENT: Prof. C. LAPWORTH.

NEW MEMBERS OF COUNCIL:

Mr. T. H. BAYLEY. | Mr. W. H. DUIGNAN.
Mr. FRED BROWN. | Mr. F. A. GRAYSTON.
Mr. HUBERT GIBBS.

Mr. F. G. MEACHEM proposed a vote of thanks to the retiring-President (Mr. J. Lindop) for his services during the past year.

Mr. C. H. TREGLOWN seconded the motion, which was unanimously adopted.

Mr. LINDOP, in acknowledging the resolution, expressed satisfaction at the great improvements which had taken place since he was first connected with mine-engineering.

The PRESIDENT (Mr. F. G. Meachem) then delivered the following "Presidential Address":—

PRESIDENTIAL ADDRESS.

By F. G. MEACHEM.

In addresses that you have heard from gentlemen, who have previously held the office of president, mining in all its branches has been so completely discussed, that scant material is left, wherewith to weave an address.

I hope to place before the members a few economic considerations, which seem of paramount importance to us as a body of specialists, and to the coal and iron trades upon which the greatness of the British nation has been built and its near future depends. It is well to pause, occasionally, to review the time that has passed, to consider the varying chain of events, and to note their effect upon matters which concern us most.

The present selling price of coal is a matter for congratulation which the coal trade at large may certainly share, and the hope for continuous prosperity of the coal and iron trades must naturally possess all of the members. We hear on all sides outcries against the coal-owner, the coal-getter, and the coal-dealer; and the newspaper press lends its aid in producing and maintaining a state of hysteria, without enquiring into the causes, or comparing a low-price era with an era of high prices, and producing thereby, a rational mean average. If such a comparison were made the highest price reached would not counter-balance the effect of the lowest price; it would, at most, only show that the coal trade realized a rational profit. The following prices from the certificates of the South Staffordshire Wages Board prove that prices in the past have been favourable to the consumer.

Year.	Selling Price of Coal per Ton. s.	d.	Year.	Selling Price of Coal per Ton. s.	d.
1864	8	6	1890	7	6
1870	7	6	1895	6	0
1880 ...	7	6	1898	6	0
1887	6	6	1900	10	0

No doubt, colliery-owners have enjoyed one or two profitable years, but even in these exceptional cases, if anyone will strike an average over a series of years, they will find that a return of 5 per cent. has not been received over the total life of many collieries, especially after making due allowance for the exhaustion of the estate. Further, the terrible loss of life and enormous loss of capital caused by floodings, fires and explosions must be taken into consideration when cheaper fuel is demanded.

Various factors have combined, during the past few years, to cause a prosperous time like the present. Increased demand should be placed first, as it always affects trade in the direction of better prices and higher wages, but it seems that a series of circumstances, other than increased demand, underlies the present condition of the coal trade. One of the most noticeable is that the output per man per year which was 328 tons during the 10 years ending 1890, was only 298 tons during the 9 years ending 1899, a decrease of 30 tons or 9 per cent. per man, and this decrease certainly will not diminish the getting cost.

The widespread and resolute combination among miners (possible only owing to increased education), forcing up the rate of wages, has necessitated a similar combination among mine-owners, and a resolution (born of necessity) to sell only at remunerative rates. Thus, all collieries that could not work at a remunerative rate and pay the high standard of wages and other costs have been gradually closed, and have consequently freed the field from a great deal of underselling. Competition has grown less aggressive between coal-owners, and I would suggest that the future welfare of the coal trade lies in co-operation rather than in competition. A minimum selling price which shall be a remunerative one, seems as necessary for the colliery-owner as a living wage for the workmen. The attitude of miners in respect to their hours of work and rates of wages shows no indication of weakening, so that selling prices must continue higher than they have been during past years, if collieries are to work at a profit.

Another item of enhanced cost is the increased assessment of collieries for purposes of local taxation, which very materially adds to the expense of working at many collieries.

The Workmen's Compensation Act has increased the working cost by about 2d. per ton, and as this was a gift of the public to the miners, it is only reasonable that the public should pay for it.

Timber, a most important item at collieries, has increased very considerably in cost, and the same may be said of all stores used; and when the extra cost of stores is added to the 60 per cent. added to wages since 1888, the total increase of cost amounts to a very considerable item.

The greatness of nations largely depends upon the development of industries, and the possession of metals suitable for industrial purposes. Our advancement was an absolute certainty when iron was first melted from its ore by the use of coal-fuel, and was followed by an epoch of industrial prosperity and an increase of knowledge.

Let the members picture what would have been the present condition of this country, if its production of iron and steel had been dependent upon the use of wood as fuel: a small quantity of metal only could have been made, realizing high prices, at the cost of a disforested country; there would be no locomotives or railways, no steamships, and a restricted food-supply, while with coal as fuel, exactly the opposite conditions prevail to-day. It is very evident that the coal and iron trades constitute the foundations of Great Britain's industrial greatness.

As the high prices of fuel affect manufacturers and admit of keen foreign competition, I would suggest that the coal and iron trades should form a representative board who would collate information as to the selling prices of foreign-made iron in British markets, and would be empowered to fix the price of coal, from time to time, so that iron should be made at such a price as would enable British makers to compete on favourable terms with foreign-made iron in the markets of the world. The household consumer would not receive the same favourable terms as the manufacturer of iron, but the observance of careful economy in household consumption would minimize the effects of high-priced fuel.

An export duty has been proposed as a means of forcing lower prices from coal-owners by limiting exportation, and thereby forcing a greater dependence on the home market: this would be manifestly unfair to the coal-owner, who could equally demand a duty upon machinery.

It is evident that a tax upon raw produce or manufactures is not a remedy, and while restriction would prevent rapid expen-

diture of our fuel, an export duty would not produce that result. If coal is a necessity to the foreign purchaser an export duty would compel him to pay a higher price, but would not restrict him from purchasing up to his requirements. In 1888, 26,970,536 tons of coal were exported, and in 1899, 43,111,404 tons, an increase of 16,140,868 tons in 11 years. These figures show how little inquiry had been made into facts before a remedy was proposed for an evil that existed only in imagination. The respective exports of fuel during the same years to some of our chief competitors in trade were:—Belgium, 241,195 and 778,837 tons; France, 4,193,185 and 6,870,365 tons; Germany, 3,066,557 and 5,058,573 tons; Holland, 295,598 and 1,288,829 tons; Italy, 3,471,741 and 5,526,995 tons; and Spain, 1,621,730 and 2,291,439 tons. These large increases have no doubt been principally used for the naval coaling-stations of those countries; and, consequently, the additional coal-exports have not made, in my opinion, any difference to the general export trade of Great Britain. It may be noted that the increased coal-exports have been made to countries from whence our ships bring back cargoes. It is the price of fuel to British ironworks that has raised British iron to so high a price as to admit of foreign-made iron competing with us in all the markets of the world.

The exports of coal to British colonies have fallen from 4,245,319 tons in 1888 to 2,228,716 tons in 1899, showing a decrease of 2,016,603 tons, and proving that our colonies are commencing to use their own stores of fuel. For instance, Canada has reduced her imports by one half in 10 years, and India has done the same.

It is difficult to forecast future events, and determine how long the present high prices will last, but it is certain that the time is coming when by force of circumstances coal will sell at a high price, even under normal conditions. The area of coal-mines working at shallow depths is daily being limited, and coal lying at great depths will soon be the only source of our supply.

Mining at great depths, in addition to the initial expense of sinking, is more costly than shallow mining: the standing charges are heavier; the cost of timbering is doubled and in some instances even trebled; and the cost of repairing roads is even greater; and fires in mines over 2,000 feet deep are another costly item. These extra charges will so materially increase the cost

of production that the era of high selling prices will certainly become permanent.

When that time is reached, an immense impulse will be given to the search for substitutes for coal. Peat, however compressed, though it might be suitable for household purposes, does not produce sufficient heat for manufactures, the smelting of ores, or raising steam. Bituminous shales are found in various formations from the Oxford Clay downwards, and possibly some of them might be used as fuel, where forced draught can be applied. Lignite does not exist in sufficient abundance in this country. The use of appliances for the conservation of heat, and the utilization of gaseous products will no doubt prove economical and to some extent reduce the demand for coal.

Dr. J. H. POYNTING read the following paper on "The Nature of Electric Current":—

THE NATURE OF ELECTRIC CURRENT.

By Dr. J. H. POYNTING.

Whenever electrification is produced, equal quantities of positive and negative are formed. These opposite charges are always inducing each other, across the air or other insulating medium, and tending to reunite and neutralize each other. Discharge is always reunion and mutual destruction. Faraday showed that we may regard the insulating medium as the chief seat of the action. It is in some way altered, is subjected to "electric strain," which may be symbolized by the passage through it of lines of electric force similar to the lines of magnetic force round a magnet. This strained condition of the insulator is most conclusively proved by Prof. Kerr's experiment in which carbon bisulphide, between two charged conductors, is shewn to behave like a crystal as regards the passage of polarized light. When discharge takes place, this condition of strain is propagated sideways into the line of the discharge. The conducting material, whether it be a metal wire, or a portion of the air or insulator rendered "conducting" by the passage of a spark, is incapable of storing the strain, and as fast as the strain comes in to the line of discharge its energy is dissipated, usually as heat. A conductor behaves with regard to electric strain as a liquid behaves with regard to ordinary shear strain.

But the nature of the discharge may be best studied in the case of a voltaic battery. As long as the circuit is open the one terminal is positively charged, the other negatively charged, and the two charges are connected by lines of force through the intervening air. The air is the seat of electric strain and is storing energy. On completing the circuit, the positive and negative rush together. Continual supplies of the two are formed, and the rushing together is continuous. We must suppose the electric strain in the air round the wire to be continually propagated into the wire, there to be dissipated and as continually renewed from the battery. This motion of the strain symbolized by the side-

ways sweeping of the lines of force stretching from positive to negative through the air is accompanied by a magnetic effect, and there are lines of magnetic force round the line of discharge.

The relation of the electric strain to the magnetic action when a current is established may be compared to the relation between strain and motion in ordinary machinery. An engine supplying power strains the belting, shafting and wheels. But in order that the energy shall travel from the engine to the working points it is necessary that the intervening machinery shall move. So in the electric current the machinery is in the surrounding air or insulator. It is electrically strained, but in order that the electric energy shall travel from source to wire the machinery must be moving and its motion is manifested in the magnetic condition of the medium.

The wire therefore is only the axis of the current. The working is going on in the space all round and the strain and energy are coming into the wire from that space. This theory may be illustrated by the transmission of signals through a submarine cable. If the core be put to the positive terminal of the sending battery a positive charge flows along the core and the corresponding negative along the inner surface of the conducting sheath. The lines of force sweep through the insulating matter between the two, and the insulator is the seat of magnetic action. The energy which finally emerges at the receiving instrument has travelled through the insulating material. Another illustration may be found in the ordinary transmission of electric signals by a circuit earthed at each end. If positive is travelling along the wire negative is travelling with it along the ground underneath, and the lines of electric force connecting the two are sweeping along through the air. The so-called "earth-return" is not a return at all, but merely a convenient passage for the outgoing charge of the kind opposite to that sent along the wire.

The PRESIDENT moved a vote of thanks to Dr. Poynting for his valuable paper.

Mr. H. LEA seconded the resolution, which was cordially approved.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD AT THE BIRMINGHAM UNIVERSITY, DECEMBER 10TH, 1900.

MR. F. G. MEACHEM, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

DISCUSSION OF MR. F. G. MEACHEM'S NOTES ON "THE HAMSTEAD COLLIERY FIRE."*

Mr. F. G. MEACHEM said he was fully convinced that the oxygen in the air was the sole agent in producing fires in coal-mines, and that the effect of the mechanical heat produced by working the coal was practically *nil*. He suggested that it would be desirable, during the absence of the workmen, to create in the workings an atmosphere in which there was little oxygen, and then fires could not be generated, as there would be no chemical action.

Mr. W. B. COLLIS (Stourbridge) said that he had considerable experience with underground fires, especially in the Thick coal-seam of South Staffordshire. He had held the opinion for many years, and he saw no reason to change it, that these fires were produced by the rapid absorption of oxygen by finely-divided particles of coal, created by grinding action due to dislocations or faults or arising from the superincumbent weight. Heat was thus produced, and as it increased the absorption of oxygen became more rapid, until the coal burst into flame. He considered that there were two satisfactory methods of dealing with these fires; either to prevent all access of air by completely enclosing the fire, or to open out the

* *Trans. Inst. M.E.*, vol. xviii., page 486.

fire and to direct as much cold air upon it as possible. The selection of the right one of these two methods involved the exercise of judgment, which could only be attained by experience, and a knowledge of the circumstances of the mine. He agreed with the President that there might be occasions when it might be desirable to prevent the access of air to the working-places, so as to limit for a time the supply of oxygen; but he preferred to apply cold air to fires, where it could be safely applied.

The President had described the peculiarly fresh and unoxidized condition in which, at the re-opening of Hamstead colliery, all the articles in the mine were found; and he (Mr. Collis) had come to the conclusion that it was probably due to the slow distillation and diffusion of the products of the combustion of coal and wood —the naphthaline and carbolic acid—which would destroy all germs of life and arrest putrefaction, while the oxygen of the atmosphere was absorbed by the coal in the mine. The analysis of the imprisoned air shewed that it was nearly devoid of oxygen.

Mr. A. Sopwith (Cannock Chase) considered that, as a cause, oxidation was a proper common term to apply to gob-fires and fires in coal-pillars, but there were other exciting causes. Certain coals, no doubt, lent themselves more readily to oxidation than others, but it appeared to him that in most cases one or other of the exciting causes came into preliminary action in the case of spontaneous combustion of coal.

There is a tendency for a slow heating action to take place in the interstices of the gob or in the cracks of a wall or pillar: this action may result from the presence of finely-divided iron-pyrites and moisture, pressure, or some other exciting cause, or it may be mere oxidation; and it causes an initial warming of the coal if there be no current of air to cool it down. If the air, however, has access only in such limited quantity as to supply oxygen without cooling, then increments of heat are added, and proportionately or perhaps in increasing ratio, more rapid oxidation takes place until actual incandescence occurs. When this latter results, or when it is betrayed by the presence of what is sometimes termed "green smoke," it is advisable to cut off air, but up to that point the more air that is turned over the gob the better.

From a practical point of view, it may be contended that the suggestion of limiting the quantity of air or oxygen would be of no benefit in preventing fires, as there would always be a sufficient

quantity of oxygen. The capacity of coal for absorbing oxygen is more a question of temperature than proportion of oxygen, and it is more valuable to have a sufficient volume of air to counteract any heating tendency.

With regard more especially to fires in the so-called "solid" coal, it may be observed that the thick brown-coal seams in Austria contain much moisture, and the action of the air on the wall-sides is to form a network of cracks for some feet into the coal. The air going along a passage cannot circulate freely in these hair-like cracks, in sufficient quantity to keep down any tendency to heat, but it supplies oxygen in more or less limited quantities. Ultimately, it may require some months to initiate combustion, and when the action first indicated is accelerated by some exciting cause, actual fire results. The usual preventative plan adopted is to rake down the coal when it has warmed back to the surface, and expose a fresh uncracked surface.

Lengthened experience had led him to the conclusion that iron-pyrites, when intimately mixed with coal or its associated bands, was a potent factor in producing gob-fires, although as explained, it was not an absolutely necessary one.

Mr. F. A. Grayston (Tamworth) said it was essential that all the wrought coal should be removed from the mine, and when it was necessary to leave pillars, they should be large enough to resist the superincumbent weight. He did not think that, in Thick coal-mines, the periodical withdrawal of air would prevent the occurrence of gob-fires, and it would be a source of danger in coal-seams likely to give off much fire-damp.

Mr. Isaac Meachem, Jun. (Old Hill) said that to a great extent the cause and frequency of fires in Thick coal-mines was determined by the nature of the coal, which varied so considerably in different parts of the coal-field. He knew of a mine where the whole seam is of a hard nature, with very little superincumbent weight; the roads stand well, the openings are of unusual size, and the ribs and pillars do not crush. Fire in the roads of that mine is unknown, although the roads have been driven for many years. In other mines, the Thick coal-seam has been friable. The friable coal presents many minute "faces" to the air, and numerous crevices into which the air percolates, and in addition the coal contains minute particles of pyrites. These con-

ditions are favourable to spontaneous combustion, and form a source of worry and anxiety to the manager.

When spontaneous combustion takes place in a road, the fire should be immediately filled up, an airway should be driven to the heated portion, all possible air should be turned upon it, and when the place is cooled down it should be filled with stone-dirt. That morning, he had inspected a place in which a fire had occurred, it had been cooled down to the normal temperature of the mine, and would at once be filled with stone-dirt.

The conditions at Hamstead colliery are exceptional, the seam being fairly hard, but the weight of the superincumbent strata is so great that fissures are formed in the sides of the roads and although a large volume of air may be passing along the road, yet in these fissures it moves slowly, if at all; the oxygen of the air is absorbed by the finely-divided particles of coal in these crevices, and causes these fires, which occur mostly in the return-airways where the air is impregnated with moisture. Mr. F. G. Meachem had proposed the withdrawal of air from the mine at week-ends and holidays, but he (Mr. Isaac Meachem) did not approve of this suggestion. In his early days, he was employed at a colliery where the air was periodically cut off from the mine, and considerable trouble was experienced from fires in the roads. It was decided to discontinue cutting off the air from the mine, and to allow the current to pass continuously round the roads and working-places. The result was most beneficial, and from that time no fires occurred in the roads. When preventing the access of air to and egress of air from a mine, it should be remembered that the air is not removed from the mine, but simply bottled up, and the whole mine remains filled with air, although it is not in motion. The oxygen is still there and is still being absorbed by the coal. There is air throughout the roadways and working-places, and the oxygen is ready to be absorbed by the iron-pyrites and finely divided particles of coal. Heat and moisture are present, and no cooling air is passing through the mine to counteract the heating that ensues. In fact, the closing of the mine fosters the heating in the absence of cold air to reduce the temperature.

Mr. Alexander Smith could understand the President being impressed with the peculiar state of things that he found on re-opening the Hamstead colliery, and for the time being he was no doubt carried away with the idea that reduction of air meant

freedom from fire and had expressed the opinion that probably the old miners were right in cutting off the air when the pits were standing at week-ends and holidays. But the cases were not similar. At Hamstead colliery, the pit was closed so long that the fire would absorb nearly all the oxygen with the formation of carbon monoxide. Probably microbes could not exist then, and oxidation could not take effect, resulting in the extraordinary preservation of everything left in the mine as described by the President. In the other case, however, of only cutting off the air for a short time, the temperature of the mine would be increased and every favourable condition for spontaneous combustion would ensue, so that when air was re-admitted fires would immediately break out. In fact, an artificial condition of fire-brewing would be produced by cutting off air for a short time.

THE MINING INSTITUTE OF SCOTLAND.

EXCURSION MEETING,

GLASGOW. DECEMBER 12TH, 1900.

About 100 members visited the Port Dundas Electricity Station of the Corporation of Glasgow, and were received by Bailie Maclay, convener of the Electricity Committee, and Mr. Chamen, chief engineer, and shown over the works.

PORT DUNDAS ELECTRICITY-WORKS.

The Port Dundas electricity-station is the principal station for the supply of electric current for lighting to the city of Glasgow. It consists at present of a handsome range of buildings 558 feet in length, and there is room for extension to three times this length.

The accumulator-batteries, placed in two large rooms, can supply approximately 615 lamps of 16 candlepower for 7 hours, and are intended for use when repairs are required in the running machinery, or when only a small amount of current is on demand. The regulating-switch is novel in its design.

The engine-house extends the whole length of the building. The switchboards are placed on a gallery in the engine-room: there are positive and negative panels for feeders leaving the station, grouped in sets of eight positives and eight negatives, coloured respectively blue and red.

The plant in the engine-room comprizes: (1) Ball-and-Wood engine of 750 horsepower, coupled to two Walker dynamos; (2) Paul-Schukert set of 900 horsepower; (3 and 4) 200 horsepower and 400 horsepower Mirrlees-Watson-Crompton combination; (5) motor-driven boosters; (6) 250 amperes equalizer; (7) 500 amperes equalizer; (8 and 9) two 1,100 to 1,500 horsepower Belliss engines driving Thomson-Houston dynamos; and (10) Willans-Crompton 1,200 to 1,500 horsepower set.

The boiler-house contains 10 Babcock-Wilcox water-tube boilers, each capable of supplying steam to 1,000 horsepower. They are fitted with chain-grate stokers and steam superheaters.

The coal-store is placed behind the boiler-house, and is supplied from boats on the adjoining Forth and Clyde canal, by means of transporters.

The PRESIDENT moved a vote of thanks to the Electricity Committee of the Glasgow Corporation, and to Bailie Maclay and Mr. Chamen, which was cordially approved.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE MASONIC HALL, WEST REGENT STREET, GLASGOW,
DECEMBER 12TH, 1900.

MR. JAMES T. FORGIE, PRESIDENT, IN THE CHAIR.

The Minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. CHARLES HENRY DAVIES, 99, Cedar Street, New York City, U.S.A.
Mr. ALEXANDER GREIG, Hayfield Cottage, Slamannan.
Mr. THOMAS WEBSTER, Burdiehouse Limeworks, Loanhead.

ASSOCIATE—

Mr. JAMES KERR, 105, New Logans, Motherwell.

STUDENT—

Mr. THOMAS O'DONNELL, Bog Colliery, Larkhall.

Mr. JAMES STIRLING, Mining Representative of the Colony of Victoria, gave a lecture, illustrated by lantern-views, on the mining resources and other features of the Colony of Victoria.

Mr. J. S. DIXON moved a vote of thanks to Mr. Stirling for his interesting lecture, and the motion was cordially approved.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE GRAND HOTEL, HANLEY, DECEMBER 10TH, 1900.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were confirmed.

The following gentlemen, having been previously nominated, were elected:—

ORDINARY MEMBERS—

Mr. JOSEPH BATEMAN, Parkhall Colliery, Longton.
Mr. CHARLES DENNIS BRINDLEY, New Broad Street, London, E.C.
Mr. JAMES FERRIDAY, Manager, Old Park Colliery, Shifnal, Shropshire.
Mr. R. R. MAKEPEACE, Colliery Manager, Talk-o'-th'-Hill, Stoke-upon-Trent.

ASSOCIATES—

Mr. GEORGE LOCKETT, Under-Manager, Peacock's Hay, Chatterley, Tunstall, Staffordshire.
Mr. CHAS. SCRIVENS, Under-Manager, Hayes Wood Colliery, Halmerend, Staffordshire.
Mr. WILMOT SCRIVENS, Holly Villa, Halmerend, Staffordshire.

STUDENT—

Mr. C. A. ATKINSON, Durham College of Science, Newcastle-upon-Tyne.

The PRESIDENT read the following address:—

PRESIDENTIAL ADDRESS.

By W. N. ATKINSON.

Before beginning my address as President, I again take the opportunity of expressing my appreciation of the honour conferred by electing me to this position; and I hope that, with your assistance, any shortcomings on my part will not prevent our meetings from being spent with pleasure to the members, and also with some measure of profit to the mining community at large.

In the first place, it will, perhaps, be convenient if I refer briefly to two important questions: the one chiefly affecting the members of this Institute; and the other a subject which, in the general interest of the district, cannot be much longer neglected.

A Home for the Institute.

It has been felt for many years that the usefulness of the Institute is curtailed, and the advantages which it offers to the members reduced by the fact that it possesses no permanent home. The North Staffordshire Institute of Mining and Mechanical Engineers has done good work for 28 years, and has proved its usefulness, not only to its members but to the mining industry of the district generally; and it is unfitting that it should not have a permanent home, such as is enjoyed by mining institutes in other districts. House room is also required for our library which, by means of exchanges, increases automatically from year to year, and which if appropriately housed and cared for would attract gifts of books and papers from members and others. A mining and geological museum would also soon spring up, if we had proper accommodation for it. We ought to be possessed of geological and other maps and sections of our own coal-field at least; but without better accommodation than we have had in the past, there is no inducement either for the Institute to purchase maps or books, or for members to present them.

A mining institute such as we desire would also form a natural centre for meetings and appointments on all subjects connected with mining, engineering and other allied industries. The members are aware that this subject is now occupying the special attention of the council, and it is hoped that, with the co-operation and assistance of the colliery-owners of North Staffordshire, and others interested in the welfare of the Institute, our efforts may at last be crowned with success.

With reference to this subject, I will quote the words of the late Mr. Nicholas Wood, first president of the North of England Institute of Mining and Mechanical Engineers, the pioneer mining institute of this country. In his inaugural address on September 3rd, 1852, Mr. Wood said:—

> Our Institution is in the first place, therefore, intimately connected with the interests of all the proprietors of coal, and all the lessees of mines of this district; or what is generally termed the coal-owners of the north. Our claims to their support are all-powerful. We are associated together for the prevention of accidents in mines. Who so interested in the prevention of accidents as coal-owners? Past experience shows that they are never behind the most energetic philanthropist in attention and care to the sufferings of the injured, or victims of those dreadful accidents, or in alleviation of the misery and distress of their relatives and families; on this ground alone, we seek to have their support. But we are also associated together for the improvement of the art of mining scientifically, practically and economically. The coal-owner, or worker of the coal is therefore, on that account, likewise most materially interested in the success of the Institution. And as one of the prominent features of the Institution is to endeavour to accomplish the best and most perfect mode of abstracting the coal, so as to produce the largest quantity of coal out of a given area of mine, the proprietor of the coal, as well as the worker of it, is no less materially interested in the success of the Institution.*

These remarks apply in the fullest sense equally to the North Staffordshire Mining Institute as to the North of England Institute.

Scientific and Technical Instruction.

The second subject to which I wish specially to refer is that of scientific and technical instruction, and this is a question affecting the whole of the mining and manufacturing interests of North Staffordshire. The Mining Institute, since its formation, has endeavoured to supply, in some measure, the requirements of its younger members in this respect. At different times, courses of

* *Trans. N.E. Inst. M.E.*, 1852, vol. i., page 5.

lectures, by competent authorities, on scientific and technical subjects relating to mining, have been arranged and paid for by the Institute. In this way lectures, or a course of lectures, have been given by Dr. Hill, Mr. G. G. André, Dr. Carnelly, Prof. Williamson, Prof. A. Lupton and Prof. J. H. Merivale. In the most recent lectures by Mr. de Rance, Mr. Turner and Prof. Dixon, we were assisted by the County Council. It is quite evident, however, that such intermittent methods of education, however valuable in themselves, are quite inadequate to meet the needs of mining students who wish to qualify themselves to compete with their fellows in more favoured districts, or to deal efficiently with the practical questions constantly arising at large collieries fitted up with all the costly modern appliances, and where the work has to be carried on under conditions of great natural danger.

It is generally admitted that, as a nation, we lag behind many of our foreign competitors in the matter of scientific and technical education. On this point I will quote the following passage from a recent address to the Leeds Chamber of Commerce by Mr. Asquith, late Secretary of State for the Home Department:—

> What I venture to say to you is this—let any man in this room read, as I doubt not the majority of you have read, the accounts of what is done and provided in France, in Germany, in Belgium, in Austria, and above all in the United States of America, and let him contrast the magnificent educational apparatus to which the humblest boy in those countries may hope and aspire to be a participant with our own scanty, slovenly, unscientific, ill-organized system or want of system; and when he has made the comparison he will no longer be at a loss to understand why England is handicapped in the race for commercial supremacy.

North Staffordshire has certainly not advanced equally with most other centres of British industry in providing facilities for the proper training of the men who will in the future be called on to direct and manage the local industries.

For some years past, the County Council has done good work in the district by the appointment of lecturers, one of whom is a lecturer on mining, and by the formation of evening classes at convenient centres; and it is understood that the County Council is prepared to contribute further to any satisfactory scheme receiving local support. Personally I am not convinced that the County Council has sufficiently considered the requirements of this important district, in dealing with the funds allocated by Parliament, primarily for the advancement of technical instruction, and I would respectfully urge the gravity of the subject on the councillors representing the northern parts of the county.

The higher educational needs of the district have recently found expression in the Report of a Committee of Enquiry, and the work thus commenced is being carried on by an Executive Committee, whose aim is the establishment of a College for North Staffordshire; and I think that the Committee will receive the hearty support of this Institute.

It is evident that it is to the interest of mine-owners and manufacturers generally, that better facilities should be provided locally for advanced instruction in the sciences and technical questions bearing on all the industries of the district; and for this, if for no other reason, they should give moral and pecuniary support towards the advancement of such instruction.

The Coal Question.

The question of the duration of our coal-supply is one which appears to attract popular attention by fits and starts, and the recent increase in the price of coal has again caused it to become a subject of public discussion. Since Dr. Edward Hull called attention to the question in his *Coal-fields of Great Britain*, the matter has been considered, from a scientific point of view, by many writers as well as by a Royal Commission. In 1859, Dr. Hull estimated the quantity of available coal at 79,843,000,000 tons down to a depth of 4,000 feet, and this was considered reassuring, because at the then rate of production this would have sufficed to last for 1,000 years. The depth-limit of 4,000 feet adopted by Dr. Hull has been retained by subsequent enquirers, and is based chiefly on the probable temperature prevailing at that depth.

In 1865, Prof. Jevons, in a book on *The Coal Question*, stated that the annual consumption of coal for the previous 10 years had increased at an average rate exceeding 3½ per cent. over each previous year's consumption; and taking this as a basis he showed that "if our consumption of coal continue to multiply for 110 years at the same rate as hitherto the total amount of coal consumed in the interval will be 100,000,000,000 tons." This was a somewhat alarming conclusion in view of Dr. Hull's estimate of the amount of coal available, namely, 79,843,000,000 tons, or a later estimate of 83,000,000,000 tons which Prof. Jevons had before him.

A Royal Commission was appointed to consider the subject in 1866. In 1871, the Royal Commission reported that there were 146,480,000,000 tons of coal "which may be reasonably expected

to be available for use." This was nearly double Dr. Hull's estimate, and in a later edition of *The Coal-fields of Great Britain*, Dr. Hull says:—

> The discrepancy in the two results was chiefly due (1) to the Commissioners having included in their calculation coal-seams between 1 and 2 feet in thickness purposely omitted by myself; (2) to the Commissioners having made a smaller deduction for waste and loss in the working of the coal; and (3) to the Commissioners having boldly estimated the quantities under certain districts overspread by formations newer than the Carboniferous which I hesitated to deal with: not because I doubted the existence of the coal there, but from a fear of overstating the case. With the course adopted by the Commissioners in the two last cases, I now fully concur; but I still object to the comprehension of seams under 24 inches in thickness in estimates of the available quantities at great depths.

The Commissioners gave an estimate, calculated by Mr. Price Williams, of the duration of the 146,480,000,000 tons of coal before mentioned, based on a diminishing rate of increase of coal-consumption per head of the population, the population being also estimated as increasing at diminishing rates. According to this estimate the quantity would be entirely consumed in 360 years when the estimated population would be 131,700,000: the present population being about 41,000,000. The Commissioners also give another calculation founded on arithmetical instead of geometrical progression in the rate of consumption of coal, by simply adding a constant quantity equal to the annual average increase of the preceding 14 years, which was about 3,000,000 tons. Upon this basis they arrived at the following results, namely:—at the end of 100 years (1971) the consumption would be 415,000,000 tons per annum, and the estimated quantity of coal available for use would represent a consumption of 276 years.

A diagram, issued with the *Annual General Report on the Mineral Industry of the United Kingdom* for 1895, shows that the actual output from 1860 to 1895 had increased more nearly by arithmetical progression, with an annual increase of 3,200,000 tons, and this does not approach any curve representing a geometrical rate of increase.

Dr. Hull still maintains that the estimated available coal of the Commissioners is too high, and in his book on *Our Coal Resources*, published in 1897 he estimated the quantity available at the close of the nineteenth century at 81,683,000,000 tons. Deducting the amount of coal produced since the Commissioners' Report was published (estimating the output for 1900 at the same figure

as the year before) namely, 4,903,000,000 tons, from their estimate of 146,480,000,000 tons, we find that 141,577,000,000 tons are still available as compared with Dr. Hull's estimate of 81,683,000,000 tons. I do not venture an opinion as to which of these estimates is nearest the mark, but I agree with Dr. Hull that seams below 2 feet in thickness should not be included in such estimates. Such seams will no doubt be worked, and are to a certain extent worked now, but it is improbable that they will be worked extensively until the average price of coal is considerably higher than at present. To what extent this consideration may account for the large difference between the two estimates I have not been able to discover.

In 1883, the late Mr. G. C. Greenwell read a paper* on the subject, in which he pointed out several objections to the theory that the production of coal would continue long to advance either in arithmetical or geometrical progression; and the deduction that he drew from his handling of the statistics was "that after no long period the maximum of the production of British coal will have been attained." He estimated the time when this maximum would be reached as being between the years 1930 and 1940: the estimated output in the latter year being 314,365,804 tons.

In 1891, Mr. W. Cochrane, in a presidential address to the North of England Institute of Mining and Mechanical Engineers expressed the opinion "that a closer approximation to the wane, not the exhaustion, of the coal-industry in Great Britain, will be to estimate 75 years hence rather than 100."†

In April, 1900, Mr. T. Forster Brown read a valuable paper before the Society of Arts on our coal-supplies, in which he adopts Dr. Hull's figures, and stated that:—

> Whilst we have in Great Britain large unworked coal-resources, sufficient probably to maintain a rate of working exceeding our present annual output for 300 years, or thereabouts, we are now rapidly exhausting the cream and cheapest of these resources; and in fifty years or thereabouts the greater part of the most valuable of our coal-supplies will have been exhausted, except only such as can be worked at a greatly increased cost, which after half a century will rapidly increase.

Mr. Forster Brown goes minutely into the reasons which lead him to the above conclusions, and his paper is one worthy of the most careful consideration. He urges that, in order to prolong the

* *Trans. N.E. Inst. M.E.*, vol. xxxii., page 135.
† *Trans. Inst. M.E.*, vol. ii., page 181.

period during which our manufactures may be able to compete successfully with foreign countries, steps should be taken during the half-century in which he estimates cheap coal will still be available, to cheapen our internal communications and reduce our rates and taxes, by the repayment of the whole of the capital outlay of the country in railways, docks, sanitation, water and other public workings.

In May 1899 Mr. J. A. Longden referred to the coal question in a presidential address to The Institution of Mining Engineers, in which he endorsed Mr. Forster Brown's opinion as to the supply of cheap coal, and took a somewhat gloomy view of the industrial future of this country.*

It has been suggested that a tax should be put on exported coal so as to economize our resources, and on the ground that foreign countries should be made to contribute to the British empire for being allowed to buy our coal; such taxation has also been advocated in order to reduce the price of coal at home, and 5s. per ton, or more than 50 per cent. *ad valorem* in ordinary times, has been suggested as the amount of the tax. Our exports of coal, coke, and patent fuel last year, according to a Board of Trade return, were 43,111,404 tons, or roughly, nearly 20 per cent. of our production. That any tax on exported coal would reduce the amount exported appears certain, as it would reduce the field in which British coal could compete with that of other countries, but in my opinion any saving of our coal-supply, or any benefit derivable from such a tax, would be too dearly bought. To the extent that it was operative the tax would deprive a portion of our mining population of their livelihood, and it would be likely to have a most injurious effect on our shipping industry. The incidence of such a tax would be very unequal; it would affect some collieries and some districts to a much greater extent than others. It seems improbable that such a tax would have any permanent effect on the average price of coal in this country. Its immediate effect would no doubt be to reduce home-prices, but its ultimate effect might simply be to cause the closing of mines depending chiefly on export trade.

The people whose complaints are most loudly heard when coal is unusually dear are, in my opinion, those who deserve the least sympathy. Gas companies, railway companies and other large

* *Trans. Inst. M.E.*, vol. xvii., page 319.

consumers of coal may obtain their supplies for years together at prices leaving little or no profit to the colliery-owner. On the other hand, small consumers even in mining districts always pay a much higher price for coal and usually for ready money. The very poor who can only buy coal by the hundredweight are especially to be pitied.

It is unfortunate that the coal-trade is subject to such extreme variations in prices as occur periodically, but that we shall again have cheap coal—probably, as in the past, too cheap—I have not the slightest doubt.

The Government has been urged to undertake a fresh inquiry into the subject of our coal-supplies, and no doubt further enquiry will be made sooner or later. Whenever such investigation is undertaken, one of the most important subjects calling for enquiry will be the waste of coal consequent on our system of mineral ownership and methods of working. From coal that is got, whether it is used at home or exported, and whether it is cheap or dear, some benefit is obtained; but coal that is lost, owing to conditions that are more or less preventable, is a loss to the nation as well as to individuals, which can never be retrieved. And I imagine more could be done in this direction to extend the duration of our coal-supply than is likely to be achieved in any other way. It is obviously to the interest of the owners of minerals that the greatest possible proportion of the minerals should be won, and it might be supposed that such interest would suffice to obtain the best practicable results; but all who are acquainted with the mining operations of large districts, must admit that this is not the case. I believe that a certain amount of State regulation might save much coal that is lost under the existing system, and prove to the ultimate advantage of mineral-owners, mine-workers, and the nation.

While fully recognizing the seriousness of the coal-question, and the importance of the study of, and enquiry into, all its factors, I am not disposed to take a gloomy view of the future. Our abundant supply of cheap coal in the past has made us extravagant and careless, both in working and using it. We have depended too much on our natural and physical advantages and too little on our moral and intellectual faculties, of which our extravagant production and use of coal and neglect of education are examples.

We are no longer the largest coal-producing country in the

world; the United States of North America after a long stern-chase has passed us, and is moreover able to produce coal at a cheaper rate than we are doing; their methods of coal-mining, however, are as yet even more wasteful than our own.

The resources of science are never exhausted, and means may be found by which a vastly greater proportion of the heat and energy obtainable from coal may be utilized than is possible at present.

Again there are other sources of heat and energy than coal, and it can hardly be doubted that at some future time we shall be able to dispense with the use of coal for many purposes for which it is now essential.

Use of Electricity in Mines.

The use of electricity for the transmission of power is likely to make rapid strides in this country in the early future. On the Continent and in North America, it is already utilized to a much greater extent than here. By the establishment of large generating-stations (placed where water-power is available, or where coal is cheap) electrical power can be distributed over large areas at a smaller cost to the ordinary consumer than would be incurred for the production of the same amount of power by boilers and steam-engines at individual works. It is said that electrical energy generated by water-power is often distributed in North America and on the Continent at ¼d. or ½d. per Board of Trade unit, equivalent to from £5 to £10 per horsepower per annum, and experts believe that electrical power in bulk can be generated here as cheaply from coal, while steam-power obtained from coal at factories is estimated to cost from £15 to £30 per horsepower per annum.

For the establishment of central electrical generating-stations and the distribution of the product, parliamentary powers are required, and last year a bill was promoted to obtain the necessary powers for a large district in South Yorkshire and Nottinghamshire—an area including the towns of Sheffield and Nottingham. The bill was opposed by the Corporations of these and other towns and was discharged after having passed most of its stages. In the last session of Parliament, bills of the same kind were introduced to deal with large areas in Durham, on Tyneside, in Lancashire, and in South Wales. These bills were all strongly opposed by various municipalities as an attack on their rights and duties. The

bills relating to Durham and Lancashire were passed, after the insertion of clauses safeguarding municipal rights and privileges, and regulating the prices to be charged and the dividends to be paid by the companies.

North Staffordshire presents a favourable field for the operations of a similar company, owing to the concentration of a large number of mines and factories where electric power could be used; but the urban character of much of the district is unfavourable.

Electricity presents many obvious advantages for use at mines, and the difficulties experienced in connection with its utilization underground will no doubt be overcome by experience or new inventions. The facility with which an electric current can be led to any point, and the growing necessity for labour-saving machinery will bring it more and more into use.

There are, however, risks attending the introduction of electricity into mines which cannot be ignored—such as the dangers of fires and explosions of fire-damp. I am not aware that any explosion of fire-damp has been due to the use of electricity, but in January, 1896, a fire in a mine-shaft of the Hermenegilde pits in Austrian Silesia, resulting in the loss of 16 lives, and serious peril to many more, was attributed to short-circuiting or the formation of an arc in the conductors of an electric-lighting installation. On November 25th, 1900, a fire in the workings of Newfield colliery, Normanton, was caused by electricity used for working a pump. It is clearly imprudent to introduce unprotected motors, which may constantly or at any time while working, produce sparks capable of igniting fire-damp, into parts of a mine where fire-damp may be expected and where safety-lamps only are allowed for lighting. The dangers attending the use of electricity in mines should be stringently guarded against, because a fire or explosion underground is likely to be far more dangerous than a similar accident on the surface. I think that legal regulations or special rules on the subject are required.

Explosions in Coal-mines.

The mining industry is to be congratulated on the comparative immunity which we have enjoyed for some years from disastrous explosions. These accidents formed the greatest blot on the coal-trade, and until the predominating influence of coal-dust in colliery-explosions was discovered there was little hope of prevent-

ing them. The North Staffordshire Mining Institute had a fair share in throwing light upon the coal-dust question, as may be seen by reference to its *Transactions*. It seems probable that this, the last year of the nineteenth century will be the first year on record in which a serious explosion, chiefly or entirely due to coal-dust, has not occurred in Great Britain. It is to be hoped that immunity from such disasters will not lead to any relaxation of the precautions required to prevent them, because the causes remain in full force ready to come into operation at any time; that is to say, the mines are as fiery and dusty as ever they were, and as more deep mines come into operation the area of danger will increase.

Accidents by Falls of Ground.

Falls of ground continue to be the most prolific cause of loss of life in mines, and contribute nearly half the total number of deaths due to underground accidents: the average loss of life for 10 years past has been 440 per annum. This subject has been receiving the special attention of H.M. inspectors of mines for some years, and they have come to the conclusion that a considerable proportion of these accidents might be prevented if greater attention and care were devoted to the support of the roof and sides. The methods advocated by H.M. inspectors of mines for this purpose are (1) provision of timber ready for setting in the working-places; (2) increased supervision and stricter enforcement of rules and regulations as to timbering; (3) systematic timbering; and (4) use of the ringer-and-chain or other similar device for withdrawing timber. I do not propose now to deal with this subject at any length, but I am glad to say that in this mines-inspection district there is a general disposition to give the question careful and impartial consideration.

With reference to systematic timbering, which is already adopted to a certain extent in this district, the drawing up and publication of regulations about timbering and packing is only half the battle, and it is only by the continual and strict enforcements of such regulations that their full value can be realized. Miners accustomed to support their working-places almost entirely at their own discretion will not readily adopt a different system without compulsion being used. I would urge on colliery managers and officials the careful study and discussion of this question, and not only of the difficulties but of the advantages of preventing

falls; because I am convinced that the more the subject is examined, the more it will become apparent that it is within their power to reduce accidents from falls by the adoption of reasonable precautions.

Mr. J. C. CADMAN, in moving a vote of thanks to the President for his able and instructive address, said that it would be read with interest by members of the Institute and by the mining engineers of Great Britain. He trusted that before the end of next year they would have secured a home for the Institute, a library, and a museum, and under the able guidance of their new president he (Mr. Cadman) felt sure that these objects would be accomplished. Although the County Council had done much for the furtherance of mining instruction in North Staffordshire, he (Mr. Cadman) was dissatisfied with the amount of money granted and he hoped that they would considerably increase their support.

Mr. JOHN BLAIKIE, in seconding the vote of thanks, said that the President had agreed that the nation had been negligent in the matter of coal-getting. He was afraid that in North Staffordshire they had been guilty of working the best coals, and leaving those which were not quite so good.

The motion was cordially approved.

The PRESIDENT said that he was obliged to them for the kind terms in which they had spoken of the address. It might have been much better, but, such as it was, he had had much pleasure in preparing it for the Institute.

DISCUSSION OF MR. W. GIBSON'S PAPER ON "THE UPPER COAL-MEASURES SURROUNDING THE MARGINS OF THE NORTH STAFFORDSHIRE COAL-FIELD" ETC.*

Mr. WALCOT GIBSON said that in describing the Upper Coal-measures, it might seem as if he were only dealing with the marginal deposits. By referring to the maps of the Geological Survey, it would be seen that the Upper (and unproductive) Coal-measures occupied more than two-thirds of the coal-field. The

* *Trans. Inst. M.E.*, vol. xx., page 73.

productive Coal-measures had been mined up to and under the Black Band series, and part of the Etruria Marl series, but not under the Newcastle and Keele series. When the officers of the Geological Survey returned to this district they saw the importance of an investigation of the Upper Coal-measures as affecting future extensions of the coal-field, and consequently special attention was directed to them. The Upper Coal-measures were capable of a fourfold subdivison, whose thicknesses could be accurately estimated, and if the subdivisions were correctly delineated upon a map, one could see at a glance at what depth the Bassey mine would be found below the surface.

Dr. W. HIND said that he had gone over some of the ground with Mr. W. Gibson, and he had already formed an idea that some day they would be pestered at Stoke with collieries, because coal would be found at a reasonable depth at that place. He agreed with the subdivision of the Upper Coal-measures suggested by Mr. Gibson, and was interested in the fact that certain fossils, typical of each series, were found. A tiny fossil, *Anthracomya calcifera*, so far as he was able to ascertain, was confined to certain parts of the Newcastle-under-Lyme series. It had a shell, ¼ inch long, and it was found in some of the limestones. If it was confined to that series it would be a guide in mining explorations. Another fossil, typical of the Black Band series, was known as *Anthracomya Phillipsii*. Last year, while looking over some fossils for the Geological Survey of Scotland, he came across a slab containing this fossil, and from its appearance he would have thought that the slab came from the Black Band series of North Staffordshire. These fossils showed that similar conditions of deposition existed in Staffordshire as in Fifeshire. The various beds could be more easily identified if attention were directed to the fossils contained in them. Mr. Gibson suggested that the beds thinned out towards the margin of the coal-field. That was so at Wigan, where all the intervening beds between the coal-seams were thicker at the centre than at the margin; and he thought that fact could be borne out in other coal-fields. He had come to the conclusion that British coal-fields were never very largely continuous, but had been deposited in the form of basins, and consequently a greater thickness was met with in the centre than towards the margin. Fossils seemed to be found more plentifully near the margin than towards the centre of the North Staffordshire

coal-field. He did not think that coal was formed of big trees or forests, but from lowly organisms such as peat-moss, and towards the margin the peat-beds would be closer together than in the central hollows. The attenuation of the beds at Silverdale and Halmerend showed that the margin of the coal-field was near. If the Bassey mine could be found in that district they would have datum-lines from which they could ascertain whether the beds were the same as on the other side. It was usually assumed that the bottom seam, worked on the western side, was the Bullhurst, but this had not been proved. It might correspond to some other seam on the other side, and the Bullhurst seam might be found below it.

Mr. John Cadman said that Dr. Hind had just referred to the importance of searching for the Pottery Bassey mine and the limestone-bands occurring in the Black Band series, as a means of correlation. Within the last few days, with Mr. Stobbs he had discovered *in situ*, on the west of the anticlinal axis, the limestones lying above the Pottery Bassey mine, being the datum-line, which previous to this discovery had never been seen west of the anticlinal axis. He had also observed that the measures lying between these two bands of limestone, which in the east of the coal-field are some 30 feet thick, had entirely or almost entirely thinned out, there being only ¾ inch of grey shale intervening; this thoroughly confirmed what both Mr. Gibson and Dr. Hind had said with reference to the thinning-out of the measures towards the west. The bottom limestone that he had found was 4½ inches thick, hard, brittle, very fine-grained and compact, breaking with a somewhat flinty fracture, containing *Carbonia*; above this limestone was ¾ inch of white shale; immediately above which a black limestone 12 inches thick was found, very rich in *Carbonia*, fish- and plant-remains, and scattered pipes of coal. This limestone splits easily and when broken emits a bituminous smell. He had also found 7 feet above this black limestone, an irregular band of limestone of the same kind as the bottom band, varying in thickness from 2 to 6 inches. He supposed that this was one of the limestones referred to by Mr. Gibson when he described these limestones as "two or more thin bands." The horizon at which he had found these limestones was 67 feet below sea-level at B.M. 113 on the road from Silverdale to Keele, lying at an angle of 24 degrees and dipping south 8 degrees east. Mr. Gibson concluded

his paper by suggesting that the measures to the west were disconnected during their deposition from those to the east. He (Mr. Cadman) thought that his find combatted that theory, as these limestones were now found at the same horizon both east and west of the coal-field and yielding the same fauna.

Mr. J. T. Stobbs remarked that reference had been made to the duration of our coal-supply. That duration depended very largely upon the extent of Coal-measures under more recent deposits. In searching for Coal-measures by boring through the overlying deposits, the work of Messrs. Gibson and Wedd must be of the highest value. Mr. Gibson had pointed out that in North Staffordshire they had the key to the measures overlying the workable coal-seams in the Midland districts, which had been last mapped as Permian, having previously been described as Upper Coal-measures. This confusion in the nomenclature of geologists did not assist mining engineers, who had got into the habit of regarding the whole series as the New Red Sandstone, and it would be some years before that name would be eliminated.

In the sinkings at Sandwell Park and Hamstead collieries in South Staffordshire, it had been reported that *Spirorbis*-limestones were passed through, and it would be of some importance if Mr. Gibson could say to which of the 8 or 9 limestones described by him in this district these strata could be referred.

Mr. Walcot Gibson, replying to the remarks of Dr. Hind as to Coal-measures being deposited in basins, said that was true not only of the North Staffordshire coal-field, but also seemed to be true of South Wales. In Monmouthshire, all the measures, including the limestones, thinned out to the north-east, showing that the edge of the basin of deposit lay in that direction. The discovery made by Mr. Cadman and Mr. Stobbs was most important. Mr. Wedd and himself (Mr. Gibson) had tried several times to find the Bassey mine and its limestone on the anticlinal axis, but they could never find it at Apedale or Silverdale. He did not see that its presence there opposed the idea that there was an eastern or western area of deposition. In the western part of the anticline, the coal-seams were closer together than in the eastern area. In his paper, he (Mr. Gibson) had not mentioned all the thin limestones above the Bassey mine, and the dark limestone at Silverdale, mentioned by Mr. Cadman, seemed to correspond very nearly

to one in the eastern area which contained fish-remains and *Anthracomya Phillipsii*. Above this bed in the eastern area, there were thin bands of limestone, with the curious little fossil, *Carbonicola Vinti*. Other bands of limestone were developed higher up in the series, but they were not persistent. Mr. Cadman's discovery was important, as showing that most of these limestones were present in the western part of the district. Mr. Stobbs mentioned that the officers of the Geological Survey had included the so-called Permian in the Coal-measures. It was an important point to recognize that these red sandstones were different from the Trias, a difference which had not always been recognized when describing the measures to the west. He (Mr. Gibson) had stated in the *Summary of Progress of the Geological Survey* for 1898, that the measures did not descend uninterruptedly towards the west, but rose again; and he still thought that the productive measures might lie nearer the surface than at first appeared. This could be easily proved west of Leycett, at a small expenditure of money.

Mr. J. T. Stobbs asked whether in small exposures, there was a ready means of determining a Keuper sandstone from an Upper Coal-measure sandstone. For example, if we compared the Keuper sandstone section at Forsbrook with the Upper Coal-measure sandstone section at Penkhull, they were found to be exceedingly like each other in material, colour, form of bedding, and both had an absence of fossils. Was there any test which would decide for us on the ground the formation to which the beds should be classed?

Mr. Walcot Gibson said that Mr. Wedd and himself had had great difficulty in settling the age of the sandstone in Lindley Wood, and it was only after examining the Trias at Beeston Castle and elsewhere that they agreed upon the Triassic age of the sandstone at Lindley Wood.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS, AND THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

JOINT MEETING,

HELD AT BLACKWELL, NOVEMBER 1ST, 1900.

MR. MAURICE DEACON, PRESIDENT OF THE CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS, IN THE CHAIR.

The collieries belonging to the Blackwell Colliery Company, Limited, were inspected by the members under the guidance and direction of Mr. J. T. Todd, general manager.

A cordial vote of thanks was accorded to the Blackwell Colliery Company, Limited, for their hospitality and kind permission to inspect the collieries.

The SECRETARY of the Chesterfield and Midland Counties Institution of Engineers announced the election of the following gentlemen:—

MEMBERS—

Mr. PHILIP BEAUMONT, Colliery Manager, Church Gresley Colliery, Burton-upon-Trent.

Mr. G. W. BRADFORD, Manager, Birley Collieries, Sheffield.

Mr. FEATHERSTONE FENWICK, Colliery Owner, Newcastle-upon-Tyne.

Mr. GEORGE J. GERMAN, Colliery Manager, Reservoir Colliery, Ashby-de-la-Zouch.

Mr. R. H. F. HEPPLEWHITE, Colliery Manager, Pentrich Colliery, Derby.

Mr. HENRY WALKER HILL, Mechanical and Consulting Engineer, Church Gate, Nottingham.

Mr. WILLIAM HORSLEY HUMBLE, Colliery Manager, Oxcroft Colliery, Bolsover.

Mr. ROBERT LAVERICK, Colliery Manager, Sutton Colliery, Mansfield.

Mr. PERCY WILLIAM LEWIS, Mining Engineer, Albert Street, Derby.

Mr. W. J. MORRIS, Mechanical Engineer, Sheepbridge Coal and Iron Company, Limited, near Chesterfield.

Mr. JOHN POXON, Colliery Manager, Warsop Main, near Mansfield.

Mr. DAVID RUSHFORTH, Mechanical Engineer, The Clay Cross Company, Limited, Clay Cross.

Mr. HENRY ROWBOTTOM WATSON, Colliery Manager, Loscoe Fields, Codnor, near Derby.

ASSOCIATES—

Mr. WILLIAM BATES, Enginewright, Birley East Colliery, Sheffield.
Mr. EDWARD FARNSWORTH, Colliery Engineer, Pye Hill Villas, near Nottingham.
Mr. JAMES SEARSTON, Assistant-Manager, Pye Hill, near Nottingham.
Mr. JOHN WRIGHT, Under-Manager, Hucknall Torkard Colliery, Nottingham.
Mr. WILLIAM WRIGHT, Under-Manager, Pollington Colliery, New Brinsley, near Eastwood, Notts.

STUDENTS—

Mr. OSWALD JEFFERSON BAINBRIDGE, Mining Student, Blackwell Collieries, Alfreton.
Mr. HARRY DAVIDSON ORR, Mining Student, Langwith Colliery, Mansfield.
Mr. JOSEPH CRESSWELL ROSCAMP, Mining Student, Hucknall Torkard Collieries, Nottingham.
Mr. WM. DYSON ROWLEY, Mining Student, Sheepbridge, Chesterfield.
Mr. CHARLES R. SAMS, Mechanical Engineer, Shipley Collieries, Derby.

The SECRETARY of the Midland Institute of Mining, Civil and Mechanical Engineers announced the election of the following gentlemen:—

MEMBERS—

Mr. GEORGE WILLIAM BRADFORD, Colliery Manager, Birley Collieries, Sheffield.
Mr. THOS. H. BRIERLY, Mining Engineer, Cheltenham Villa, 282, York Road, Leeds.
Mr. W. BUXTON, Colliery Manager, Altofts, Normanton.
Mr. THOMAS COOK, Steel Manufacturer, Glasgow Steel and File Works, Sheffield.
Mr. HORATIO ESHEVARRIETA, Mine Owner, Bilbao, Spain.
Mr. NAMBU KINGO, Mining Engineer, Mitsubishi Company, Tokio, Japan.
Mr. W. D. LLOYD, Mining Engineer, Altofts, Normanton.
Mr. J. LEONARD MICKLETHWAIT, Mining Engineer, Haigh Hall, Barnsley.
Mr. WALTON ROUTLEDGE, Colliery Engineer, Glasshoughton Collieries, Castleford.
Mr. JOHN HENRY TAYLOR, Civil Engineer, Borough Surveyor, Barnsley.
Mr. JOHN TINSLEY, Mechanical Engineer, Perseverance Works, Stalybridge.
Mr. W. M. TREGLOWN, Mechanical Engineer, 114a, Queen Victoria Street, London.

ASSOCIATES—

Mr. REGINALD ED. HORROX, Colliery Surveyor, Birley Collieries, Sheffield.
Mr. FRANK WARING WESTBY, Under-Manager, Foxholes Colliery, Methley, Leeds.
Mr. JAMES WHITFIELD, Under-Manager, Glasshoughton Collieries, Castleford.

BLACKWELL COLLIERIES.

The Blackwell collieries are situated near Alfreton, Derbyshire, and comprise the A and B Winnings, and the Alfreton and Shirland pits. The A and B Winnings were sunk in 1872 and 1875 respectively, Alfreton in 1885, and Shirland was acquired in 1899.

The Deep Hard and Low Main seams are worked at the A and B Winnings, the Deep Soft and Deep Hard seams at Alfreton, and the Deep Hard, Low Main and Blackshale seams at Shirland.

A Winning.—The A Winning has two shafts, 14 feet in diameter, coal being wound from the Low Main seam at a depth of 711 feet, and from the Deep Hard seam at 537 feet, the latter being the upcast pit. Both shafts are sunk to the Blackshale seam, which was reached at a depth of 876 feet.

The winding-engines each have cylinders 36 inches in diameter by 6 feet stroke, with flat drums, 18½ feet in diameter. The double-decked cages have two tubs on each deck, which are unloaded simultaneously.

Ventilation is produced by a Guibal fan, 45 feet in diameter. The upcast shaft is fitted with self-acting doors at the surface, worked by levers.

The haulage is on the main-and-tail-rope and endless-rope systems: there being one hauling-engine on the surface and three engines underground.

On the surface, the shops, offices, etc., and underground, the shaft-sidings and stables, are lighted by electricity.

The Low Main coal is tipped upon a shaking-screen, where the slack and nut coals are taken out and subsequently divided, and the best coal is passed on to a travelling picking-belt. Trams of Hard coal are run alongside the trucks and the steam and brights are picked out by hand, the remainder being passed over a shaker-screen and divided into cobbles and slack coal.

There are 72 beehive ovens, 11½ feet in diameter, in which coke is made from Low Main slack ground by a Carr disintegrator.

Steam is raised from the waste-gases of the coke-ovens by

means of elephant type boilers. The coke is drawn from the ovens by a machine extractor, and conveyed to jigging screens by means of conveyor-belts and elevator-boxes.

B Winning.—The two shafts are each 14 feet in diameter; coal is wound from both. The depth to the Low Main seam is 861 feet and to the Deep Hard seam 684 feet.

Each of the winding-engines has two cylinders, 32 inches in diameter by 6 feet stroke, and both are fitted with automatic expansion-gear. The Deep Hard winding-engine has a flat drum, 14 feet in diameter, and the Low Main winding-engine a conical drum, 16 feet to 18 feet in diameter. The cages are double-decked, with 2 tubs on each deck, which are unloaded simultaneously.

The mouth of the Low Main or upcast shaft is provided with steel lifting-hoods, the weights of which are relieved by balance-chains. The Guibal fan is 36 feet in diameter by 12 feet wide.

The single-rope haulage is worked by two engines placed on the surface, but a large hauling-engine is being erected on the surface, for both single-rope and main-and-tail-rope haulage.

The screening arrangements are very similar to those at the A Winning.

Bricks are made for the whole of the collieries, the plant comprising brick-making machinery and 4 large Newcastle kilns.

An electric-lighting plant is now being erected, to light the whole of the surface-plant and the pit-bottoms, stables, etc.

Alfreton.—The two shafts are each 15 feet in diameter, but coal is only wound from the downcast shaft. Two seams are worked from one level, the Deep Soft and the Deep Hard, which is 54 feet lower and is reached by a drift dipping 1 in 6.

The winding-engine has two cylinders, each 30 inches in diameter, by 5 feet stroke, with a flat drum, 18 feet in diameter.

The Walker-Guibal fan is 24 feet in diameter by 7½ feet wide.

The endless-rope haulage is worked by a continuous-running engine at the surface and an endless wire-rope, driving gearing fixed at the pit-bottom. The underground gearing consists of spur-wheels geared in the ratio of 4·6 to 1, driving 4 separate surging-pulleys for working the different districts; all the pulleys

are carried by one shaft, and each is provided with a friction-clutch actuated by means of hand-wheels and screws. The haulage ropes of any or all of the districts can be stopped without stopping the surface-engine or interfering with the other districts.

The air-compressing plant for driving the coal-cutting machines consists of two Ingersoll-Sergeant engines and one Sturgeon air-compressor. Four coal-cutting machines made by the Yorkshire Engine Company and one Garforth machine are under-holing the coal to a depth of 4 feet to 5 feet, driven by compressed air.

On the surface, the offices and shops, and underground, the pit-bottoms and sidings, are lighted by electricity.

The Deep Soft coal is tipped upon a long travelling belt, where several qualities are picked out, and the remainder is screened and picked into various qualities of cobble, nut and slack coal. The Deep Hard makes steam, furnace, brights, cobbles and slack coal.

Shirland.—The shafts are sunk to the Blackshale seam, 468 feet deep, from the level of which all coal is wound. The other seams are reached by rise drifts driven across the measures. The downcast shaft is used for winding, and the upcast shaft is used as a pumping pit.

The horizontal winding-engine has two cylinders 24 inches in diameter by 4 feet stroke, with a drum 12 feet in diameter.

The single-inlet Capell fan is 12½ feet in diameter by 6 feet wide.

Large quantities of water are pumped to the surface by the pumping plant consisting of an underground Hathorn-Davey pump, with a steam cylinder 36 inches in diameter by 6 feet stroke, with rams 13 inches in diameter by 6 feet stroke. In the workings, there are three rope-driven pumps, and three 3-throw pumps driven by electricity. There are also 3 sets of pumps in the upcast shaft delivering water to the surface, namely: a bucket pump, 15 inches in diameter, and plunger sets, 14 inches and 13 inches in diameter, worked by means of rods and quadrants driven by engines placed on the surface.

The surface plant and pit-bottom is lighted by electricity.

The electric-power plant for supplying current to the coal-cutting machines and pumps consists of a Robey engine,

with two cylinders, 19½ inches in diameter by 2½ feet stroke, running at 100 revolutions per minute. The No. 1 dynamo is a compound-wound, centre-hung, four-pole, continuous-current machine running at 600 revolutions per minute, and producing 180 ampères at 420 volts. The No. 2 or spare dynamo is a compound-wound, under-hung, two-pole machine running at 450 revolutions, and producing 175 ampères at 450 volts.

There are four Clarke-and-Stephenson coal-cutting machines working in the Deep Hard seam, undercutting to a depth of 4½ feet, and one Garforth coal-cutter in the Silkstone seam, undercutting to a depth of 5½ feet, driven by electricity.

The main-and-tail-rope and endless-rope haulage is driven by an engine at the surface, and two engines in the mine.

The Deep Hard coal is tipped on to shaker-screens, which take out the slack coal, and the lumps pass to a picking-belt, where the steam, furnace and bright coals are picked out, the residue being cobbles. The Low Main and Silkstone coals are screened into three sizes, namely, best, nuts and slack coal.

There are 30 beehive-ovens, in which coke is made from the Low Main and Silkstone slack coal ground by a devil disintegrator. The waste-gases from the ovens are utilized for generating steam.

At the A and B Winnings, there are excellent workmen's institutes, comprising billiard-rooms, reading-rooms, etc., and a Boys' Brigade hall, comprising a gymnasium, reading-rooms, games-rooms, baths, etc., has been recently erected.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE HARVEY INSTITUTE, BARNSLEY, DECEMBER 8TH, 1900.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ALFRED WINTER BARNES, Colliery Manager, Barnsley Main Colliery, Barnsley.

Mr. W. J. S. BATEY, Mining Engineer, Ryton Lodge, Doncaster Road, Rotherham.

Mr. E. PARKIN, Colliery Owner, Greasbro' Colliery, Masbro', Rotherham.

STUDENT—

Mr. J. N. WALKER, Mining Student, Grimethorpe Colliery, Brierley, Barnsley.

Mr. JOHN GERRARD read his Presidential Address as follows:—

PRESIDENTIAL ADDRESS.

By JOHN GERRARD, H.M. Inspector of Mines.

My first duty is to thank the members for the great honour that they have conferred upon me by electing me President.

It is exceedingly pleasant to come back to old friends; it has been a pleasure to subscribe to your funds for 26 years, although during the past 8 years, I have only occasionally been able to attend your meetings. In that short time, there have been many changes; no longer have we the venerable presence of Mr. T. W. Embleton, first and oftentimes President; the geniality of Mr. Joseph Mitchell, who filled every office, and as Secretary, Treasurer and President did so much to promote the good work of this Institute; the wise counsel of Mr. Arthur M. Chambers; the aptness of Mr. Richard Carter; or the ability and wide experience of Mr. T. W. Jeffcock.

It is necessary to allude to these distinguished occupants of the presidential chair, as I have to ask your consideration for my shortcomings, and the want of that ability so conspicuous in all of my predecessors; and your aid, for it is only by the help of the past and present officers, the Council, and the members, that the usefulness of this important Institute can be maintained.

Every effort should be made to induce those who ought to be members and who can give honour to the Institute, to join as members. Every effort should be made by the members to attend, and to increase the interest of the meetings by being prepared to take part in the discussions, to contribute papers, to exhibit new mechanisms or engineering objects of interest, and to describe any novel mining experience. The exhibition of geological specimens might be introduced at our meetings, for the information of the members.

When in 1869, the South Yorkshire Viewers Association became the Midland Institute of Mining, Civil and Mechanical Engineers, it was clearly stated that one of the main objects of the

Institute was:—the prevention of accidents. "To discuss means for the ventilation of coal and other mines, the winning and working of mines, the prevention of accidents and the advancement of the science of mining." In passing, how fitting that H.M. inspectors of mines should be present at such meetings, to learn and to give information upon matters so closely associated with their official position. The Institute has increased its membership from about 75 in 1869 to about 270 at the present time.

The *Transactions* record valuable papers and discussions on the working and ventilation of mines, their safe lighting and the prevention of accidents. Many of the members have done much for the advancement of the science and art of mining.

Accidents in Mines.

The records of accidents in mines have so often been unfolded that it is exceedingly difficult to say anything new thereon. Repeatedly, the great improvement and the reduction in the loss of life in mining have been discussed before this and kindred Institutes. But it is now my desire to put before the members concisely and clearly the nature of the improvement that has been secured.

The earliest official record began in 1851, but it is wellknown that the list of fatalities for that year was not complete, and that the records of the output and the number of persons employed were all understated. Consequently any improvement that may be shown, as regards the accidents, is under rather than overstated. In Tables I. and II. and III. and IV., the accidents and deaths are classified in the usual way, alternate periods of five years being recorded and compared, and if the earliest period be considered unsatisfactory the following period may be taken for comparison.

In the first period, there was an average of 92 explosions per annum, causing on the average 2·5 deaths per explosion; in the second period, 59 explosions, and 3 deaths; in the third period, 51 explosions, and 3·4 deaths; in the fourth period, 29 explosions, and 7·3 deaths; in the fifth period, 18 explosions, and 10·4 deaths; and in the last period, 18 explosions, and 3·6 deaths. These figures clearly show that the number of explosions diminished, that the number of deaths per explosion increased, and that now in the last period, the number of deaths per explosion has happily diminished and again approaches that of the earlier periods.

TABLE I.—SEPARATE FATAL ACCIDENTS IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp or Coal-dust.	Falls of Side and Roof.	Shafts.	Miscellaneous Underground	On Surface.	Total.	Accidents per 1,000,000 Tons of Mineral Raised.	Persons employed Aboveground and Underground	Tons of Mineral Raised.
1.—1851-1855.									
Average per annum	92·8	350·4	204·8	88·2	44·6	780·8	13·41*	229,468	58,222,894*
Ratio per 1,000 Persons employed Aboveground and Underground...	0·40	1·53	0·89	0·39	0·19	3·40	...	...	...
Do. do. per cent.	11·9	44·9	26·2	11·3	5·7	100·0	...	...	...
2.—1860-1864.									
Average per annum	59·2	394·4	139·6	120·4	56·8	770·4	8·89*	291,172	86,627,076*
Ratio per 1,000 Persons employed Aboveground and Underground...	0·20	1·35	0·48	0·41	0·20	2·64	...	...	...
Do. do. per cent.	7·7	51·2	18·1	15·6	7·4	100·0	...	...	...
3.—1870-1874.									
Average per annum	51·6	430·0	134·0	185·0	83·0	883·6	6·93	438,568	127,492,781
Ratio per 1,000 Persons employed Aboveground and Underground...	0·12	0·98	0·30	0·42	0·19	2·01	...	...	...
Do. do. per cent.	5·8	48·7	15·2	20·9	9·4	100·0	...	...	...
4.—1880-1884.									
Average per annum	29·8	455·6	87·6	198·8	92·0	863·8	5·04	503,941	171,079,381
Ratio per 1,000 Persons employed Aboveground and Underground...	0·06	0·90	0·17	0·40	0·18	1·71	...	...	...
Do. do. per cent.	3·4	52·8	10·1	23·0	10·7	100·0	...	...	...
5.—1890-1894.									
Average per annum	18·8	427·8	83·8	210 4	119·2	860·0	4·48	674,450	191,789,652
Ratio per 1,000 Persons employed Aboveground and Underground ..	0·03	0·63	0·12	0·31	0·18	1·27	...	...	...
Do. do. per cent.	2·2	49·3	9·7	24·5	13·8	100·0	...	...	...
6.—1895-1899.									
Average per annum	18·4	425·8	62·0	235·4	114·6	856·2	3·98	704,816	214,773,656
Ratio per 1,000 Persons employed Aboveground and Underground...	0·02	0·61	0·09	0·33	0·16	1·21	...	...	...
Do. do. per cent.	2·2	49·7	7·2	27·5	13·4	100·0	...	...	...

* Coal alone.

NOTA BENE.—From 1851 to 1860, accidents at Stratified Ironstone-mines are included; from 1861 to 1872, they are not included; but these mines are now comprised under the Coal-mines Regulation Act; in 1861, there were 95 deaths. From 189', the accidents on Branch Railways, Coke-yards, etc., are included; in 1890, there were 34 deaths.

The general use of open, unprotected lights caused a number of small explosions, involving few deaths per explosion. While coal-dust, coupled with the use of large-flame-producing explosives, considerably increased the loss of life per explosion. The use of less-flame-producing explosives, followed by the Explosives in Coal-mines Order had reduced the loss of life to that of the earlier periods; a loss of life which will probably continue, so long as unprotected lights are used in mines at all liable to fire-damp.

TABLE II.—COMPARISONS OF THE RATIOS OF SEPARATE FATAL ACCIDENTS IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp or Coal-dust.	Falls of Side and Roof.	Shafts.	Miscellaneous Underground.	On Surface.	Total.	Accidents per 1,000,000 Tons of Mineral Raised.
1.—1851-1855 ...	0·40	1·53	0·89	0·39	0·19	3·40	13·41*
6.—1895-1899	0·02	0·61	0·09	0·33	0·16	1·21	3·98
Percentage	4·95	39·47	8·98	86·84	84·20	35·68	29·72
2.—1860-1864 ...	0·20	1·35	0·48	0·41	0·20	2·64	8·89*
6.—1895-1899 ...	0·02	0·61	0·09	0·33	0·16	1·21	3·98
Percentage	10·00	46·15	16·60	80·48	84·21	45·83	44·77
3.—1870-1874 ...	0·12	0·98	0·30	0·42	0·19	2·01	6·93
6.—1895-1899 ...	0·02	0·61	0·09	0·33	0·16	1·21	3·98
Percentage	18·18	61·32	26·66	78·57	88·80	60·19	57·36

* Coal alone.

On comparing the ratios of deaths, per thousand workers employed underground, of the earlier with the later period, it will be recognized that a great improvement has been effected, especially when the large increase in the number of persons employed is considered. The number of the deaths from explosions during the last period was only 9 per cent. of the number occurring in the first period, and consequently 91 per cent. of the loss of life in the earlier period had been saved.

In the first period, there were 350 accidents per annum arising from falls of side and roof, causing 368 deaths: and in the last period there were 425 accidents causing 439 deaths. But the great increase in the number of persons employed considerably affects this apparent increase: the ratio per thousand workers in the first period was 1·61 deaths; in the last period, there was only 0·62 death per thousand, and the loss of life in the latter was 38·7

TABLE III.—NUMBER OF DEATHS FROM DIFFERENT CAUSES OF ACCIDENTS IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp or Coal-dust.	Falls of Side and Roof.	Shafts.	Miscellaneous Underground	On Surface.	Total.	Deaths per 1,000,000 Tons of Mineral Raised.	Persons employed Aboveground and Underground	Tons of Mineral Raised.
1.—1851-1855.									
Average per annum	231·0	368·4	236·6	101·8	47·6	985·4	16·92*	229,468	58,222,894*
Ratio per 1,000 Persons employed Aboveground and Underground ..	1·00	1·61	1·03	0·44	0·21	4·29	...	...	...
Do. do. per cent.	23·4	37·4	24·0	10·4	4·8	100·0	...	...	...
2.—1860-1864.									
Average per annum	185·8	407·8	163·0	175·2	60·2	992·0	11·45*	291,172	86,627,076*
Ratio per 1,000 Persons employed Aboveground and Underground...	0·64	1·40	0·56	0·60	0·20	3·40	...	..	...
Do. do. per cent.	18·7	41·1	16·4	17·7	6·1	100·0	...	...	...
3.—1870-1874.									
Average per annum	174·8	441·2	146·4	202·8	85·0	1,050·2	8·2 3	438,568	127,492,781
Ratio per 1,000 Persons employed Aboveground and Underground .	0·40	1·01	0·33	0·46	0·19	2·39	...	...	...
Do. do. per cent.	16·7	42·0	13·9	19·3	8·1	100·0	...	...	...
4.—1880-1884.									
Average per annum	212·8	466·2	100·4	207·0	92·4	1,078·8	6·30	503,941	171,079,381
Ratio per 1,000 Persons employed Aboveground and Underground...	0·42	0·93	0·20	0·41	0·18	2·14	..	...	...
Do. do. per cent.	19·7	43·2	9·3	19·2	8·6	100·0	...	...	...
5. -1890-1894.									
Average per annum	188·2	440·2	95·6	235·6	120·4	1,080·0	5·63	674,450	191,789,652
Ratio per 1,000 Persons employed Aboveground and Underground...	0·28	0·65	0·14	0·35	0·18	1·60	...	...	...
Do. do. per cent.	17·4	40·8	8·9	21·8	11·1	100·0	...	...	...
6.—1895-1899.									
Average per annum	65·6	439·6	71·0	271·4	116·6	964·2	4·48	704,816	214,773,656
Ratio per 1,000 Persons employed Aboveground and Underground...	0·09	0·62	0·11	0·38	0·16	1·36	...	...	...
Do. do. per cent.	6·8	45·6	7·4	28·1	12·1	100·0	...	...	..

*. Coal alone.

per cent. of the former period, a reduction or saving of life of 61·3 per cent.

From 1851 to 1855, there were 204 accidents per annum in shafts, causing 236 deaths; and from 1895 to 1899, 62 accidents causing 71 deaths, a saving of life amounting to 90·3 per cent. This improvement has often been discussed, and it is wellknown that it has been brought about by providing efficient appliances, engines, ropes, cages and guides, but the human element remains with its liability to err, and, notwithstanding the fact that so few accidents arise from mistakes of the engineman (proof of the care taken in selecting competent men and further proving the great care taken by the men in charge of the engines) it is very generally recognized that the engineman should have every aid that mechanical skill can devise. It is also generally recognized that the use of intermediary insets in the shafts and hanging-on places requires the use of clear codes of signals and elaborate fencing, but even where such precautions exist, the liability to accident, and the costliness of labour and hindrance of the output of coal, should cause their use to be, as much as possible, limited.

TABLE IV.—COMPARISONS OF THE RATIOS OF DEATHS FROM DIFFERENT CAUSES OF ACCIDENTS IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp and Coal-dust.	Falls of Side and Roof.	Shafts.	Miscellaneous Underground.	On Surface.	Total.	Deaths per 1,000,000 Tons of Mineral Raised.
1.—1851-1855 ...	1·00	1·61	1·03	0·44	0·21	4·29	16·92*
6.—1895-1899 ...	0·09	0·62	0·11	0·38	0·16	1·36	4·48
Percentage	9·0	38·7	9·7	86·3	80·0	31·7	26·4
2.—1860-1864 ...	0·64	1·40	0·56	0·60	0·20	3·40	11·45*
6.—1895-1899 ...	0·09	0·62	0·11	0·38	0·16	1·36	4·48
Percentage	14·7	44·5	19·4	64·1	82·5	40·0	39·1
3.—1870-1874 ...	0·40	1·01	0·33	0·46	0·19	2·39	8·23
6.—1895-1899 ...	0·09	0·62	0·11	0·38	0·16	1·36	4·48
Percentage	23·3	62·3	32·1	83·3	85·4	56·9	54·4

* Coal alone.

There were 88 miscellaneous underground accidents per annum from 1851 to 1855 causing 101 deaths; and from 1895 to 1899, there were 235 accidents per annum causing 271 deaths. The ratio standard shews 0·44 death per thousand persons employed for the former and 0·38 death for the latter period, an improvement of only 13·7 per cent. It is therefore probable that any reduction

under this head would require the more general use of safety-appliances and safety methods in connection with the haulage of the tubs, and self-acting inclines. In the earlier period, a great proportion of these accidents occurred to horse-drivers and those concerned in the moving of tubs, and now a large proportion of the accidents occur to those engaged on the haulage-roads and in the drawing of the coal-tubs.

The accidents on the surface call for little observation, as they have almost kept pace with the increase in the number of workpeople employed.

The total number of accidents per annum from 1851 to 1855 averaged 780, causing 985 deaths; and from 1895 to 1899 the number of accidents averaged 856 and the deaths 964. Considered in conjunction with the increased number of workpeople employed, the improvement is about 68·3 per cent. The deaths per million tons of minerals raised are 16·92 and 4·48 respectively, shewing an improvement of 73·6 per cent.

These results prove without doubt that very considerable regard has been given to the saving of life. Owners, who have done their part, mining-engineers, much-abused colliery-managers, and intelligent workers in mines, may surely be congratulated on such excellent results. These results should stimulate the various agencies for adding to the intelligence of those employed in mines, and they should receive the support of the various districts in which special education is given.

The establishment of this and kindred Institutes is then justified, and the chief cause of their formation, "prevention of accidents," has borne good fruit.

Mr. G. A. Mitchell, in his presidential address to The Institution of Mining Engineers, stated that "the influence of inspectors of mines was very great indeed during the early period when they were first appointed. They were men of intelligence and experience."*

It may be further stated that legislation brings the laggard, the careless and the indifferent into line.

I now desire to direct your attention to Table V. which shows the total number of lives lost from 1851 to 1899. The striking feature is the loss of life from falls of roof and side (21,012 lives

* *Trans. Inst. M.E.*, 1896, vol xi., page 250.

lost) more than double the loss from explosions and forming 41 per cent. of the total loss of life.

Sir Lindsay Wood in his presidential address to The Institution of Mining Engineers remarked that "however great and satisfactory this saving of life may be, there is still ample scope for a further large reduction of the number of deaths which still take place in our mines."* Possibly Sir Lindsay Wood had in view the loss of life from falls of ground.

TABLE V.—CLASSIFICATION OF THE SEPARATE FATAL ACCIDENTS AND DEATHS IN AND ABOUT THE MINES OF GREAT BRITAIN AND IRELAND, UNDER THE COAL-MINES REGULATION ACTS, FROM 1851 TO 1899, INCLUSIVE.

CLASSIFICATION.	ACCIDENTS.		DEATHS.	
	No.	Per Cent.	No.	Per Cent.
Explosions of Fire-damp or Coal-dust	2,590	6·42	10,034	19·57
Falls of Side and Roof ...	19,978	49·54	21,012	41·02
Shafts	6,529	16·19	6,618	12·91
Miscellaneous Underground	7,640	18·94	9,517	18·57
On Surface	3,585	8·91	4,067	7·93
TOTALS	40,322	100·00	51,248	100·00

The great reduction in the loss of life from explosions may be ascribed to better ventilation, safer lamps or safer lighting, the use of safer explosives, and the recognition of the danger of coal-dust. There can be no doubt that greater improvements have been made in ventilation than in any branch of mining. In 1852, Mr. Charles Morton said that "the state of subterranean ventilation in my district varies with the physical conditions of the strata, the pecuniary circumstances of the lessees, and the scientific attainments of the managers. In some of the collieries ventilation is fortuitous, correct principles and practices are not understood, and the air-currents are impelled by natural agencies only; while, in a few others, skill and capital have already created a moderate degree of artificial ventilation, and are daily improving and augmenting it. Generally speaking, however, this department of mining is not in a satisfactory condition in the Yorkshire and Midland counties coal-fields."†

In 1854, Mr. Herbert Mackworth said that "the subject which has borne a prominent place in my previous reports, and which

* *Trans. Inst. M.E.*, 1897, vol. xiii., page 437.

† *Coal-mines: Reports of Messrs. Dunn, Dickinson, Morton, Lancaster, Wynne and Mackworth, H.M. Inspectors of Coal-mines*, 1854, page 88.

every year's experience and all statistical inquiries raise into higher importance, is the excessive mortality of miners, in consequence of the foul and stagnant atmosphere in which they work. . . . . At age 20, miners experience an average sickness of 46 per cent. more than the general class; at age 30, they have 70 per cent. . . . Some current of air must pass through the mine, as otherwise labour would stop from the lights ceasing to burn."*

Dr. Ogle in his evidence before the Royal Commission on Labour on October 27th, 1892, said that "excluding accidents, the mortality of coal-miners only slightly exceeds that of the most healthy class of men—the agriculturists; and mining, now, instead of being as it was, one of the most unhealthy of occupations, is one of the most healthy."

The use of safer lamps and safer explosives, together with the recognition of the danger of coal-dust, are now dealt with by special regulations, and are not left to anyone's discretion. So also, where support is required for under-mined coal, the distance is fixed so that the supports are spaced not exceeding that distance apart.

For 50 years, we have relied upon the discretion of the miner and the judgment of the fireman, for the safe supporting of the roofs of the working-places; but many mining-engineers now think that the discretion of the miner and the judgment of the fireman have reached their utmost limit, and that they cannot be further relied upon to reduce the number of fatalities from falls of roof.

The enforcement of a maximum distance at which the supports to the roofs of the working-places shall be fixed, in the seams or the districts of the seams, has this striking advantage, that immediately there is room, the support is required and must be set. There will no longer be the delay which now exists. The workman says "I will fill another tub" or "I will get this coal off and then set the prop," but unfortunately the fatal fall intervenes and takes away the opportunity. This is not the place, nor am I at present disposed to enter upon the question of the Courrières system of timbering, but the managing director of these mines emphatically stated that the first marked reduction in their fatalities from falls of roof was brought about by stopping the delay in setting the required supports.

* *Coal-mines: Reports of Messrs. Dunn, Dickinson, Morton, Williams, Wynne and Mackworth, H.M. Inspectors of Coal-mines*, 1855, page 116.

TABLE VI.—SEPARATE FATAL ACCIDENTS IN AND ABOUT THE MINES OF THE YORKSHIRE MINES-INSPECTION DISTRICT, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp or Coal-dust.	Falls of Side and Roof.	Shafts.	Miscellaneous Underground	On Surface.	Total.	Accidents per 1,000 Tons of Mineral Raised.	Persons employed Aboveground and Underground	Tons of Mineral Raised
1.—1851.									
Average per annum	?	?	?	?	?	46	6·81*	23,500	6,750,000*
Ratio per 1,000 Persons employed Aboveground and Underground ..	?	?	?	?	?	1·95	...	...	...
2.—1860-1864.									
Average per annum	3·8	25·4	11·4	6·0	1·0	47·6	5·20*	...	9,141,600*
Do. do. per cent.	8·0	53·4	23·9	12·6	2·1	100·0	...	...	...
2A.—1864.									
Average per annum	4	27	15	3		51	5·48*	34,500	9,300,000*
Ratio per 1,000 Persons employed Aboveground and Underground ..	0·11	0·78	0·43	0·09	0·06	1·47	...	...	...
Do. do. per cent.	7·9	52·9	29·4	5·9	3·9	100·0	...	...	..
3.—1870-1874.									
Average per annum	7·8	45·2	12·6	15·4	9·6	90·6	6·47	49,279	13,990,810
Ratio per 1,000 Persons employed Aboveground and Underground...	0·16	0·92	0·26	0·31	0·19	1·84	...	...	...
Do. do. per cent.	8·6	49·9	14·0	16·9	10·6	100·0	...	...	...
4.—1880-1884.									
Average per annum	1·8	52 0	6·6	17·2	10·4	88·0	4·60	62,102	19,142,229
Ratio per 1,000 Persons employed Aboveground and Underground	0·03	0·84	0·10	0·28	0·17	1·42	...	...	...
Do. do. per cent.	2·0	59·1	7·5	19·6	11·8	100·0	...	...	...
5.—1890-1894.									
Average per annum	1 2	44·4	8·4	20·2	15·4	89·6	4·06	86,582	22,039,056
Ratio per 1,000 persons employed Aboveground and Underground ..	0·01	0·51	0·10	0·23	0·18	1·03	...	...	...
Do. do. per cent.	1·3	49·6	9·4	22·5	17·2	100·0	...	...	...
6.—1895-1899.									
Average per annum	1·4	41·4	4·6	23·8	15·6	86·8	3·43	91,008	25,290,940
Ratio per 1,000 Persons employed Aboveground and Underground...	0·01	0·46	0·05	0·26	0·17	0·95	...	...	...
Do. do. per cent.	1·6	47·7	5·3	27·4	18·0	100·0	...	...	...

* Coal alone.

The collier soon finds out the meaning of a fixed maximum distance: I was told of a case where on being asked "What is your distance apart for props?" the collier replied, "4 feet and under," showing that he clearly recognized the meaning of maximum distance.

Tables VI. and VII., and VIII. and IX. have been prepared to show the history of mining accidents in the Yorkshire district. It would be labouring the question and wearisome to the members to state more than that these tables show the same marked improvement as that clearly shown by those for the United Kingdom. Last year, the Yorkshire district occupied the enviable position of having the lowest death-rate from falls of ground, namely 0·48 per thousand workers, the highest being 0·98 per thousand workers.

TABLE VII.—COMPARISONS OF THE RATIOS OF SEPARATE FATAL ACCIDENTS IN AND ABOUT THE MINES OF THE YORKSHIRE MINES-INSPECTION DISTRICT, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp or Coal-dust.	Falls of Side and Roof.	Shafts.	Miscellaneous Underground.	On Surface.	Total.	Accidents per 1,000,000 Tons of Mineral Raised.
2A.—1864 ...	0·11	0·78	0·43	0·09	0·06	1·47	5·48*
6.—1895-1899 ...	0·01	0·46	0·05	0·26	0·17	0·95	3·43
Percentage	13·6	58·3	11·6	300·0	294·0	64·5	62·5
3.—1870-1874 ...	0·16	0·92	0·26	0·31	0·19	1·84	6·47
6.—1895-1899 ...	0·01	0·46	0·05	0·26	0·17	0·95	3·43
Percentage	9·4	49·6	19·3	83·6	88·1	52·1	53·0

* Coal alone.

The Output of Coal.

Beginning with the first year of coal-mines inspection, and noting the probable incompleteness of the voluntary returns, during the first period of 5 years, production was probably at the rate of 58,222,894 tons of coal per annum, with an output of 253·7 tons per person employed aboveground and belowground. During the last period, from 1895 to 1899, the average annual output of all minerals under the Coal-mines Regulation Act, was 214,773,656 tons, and 304·7 tons per person employed aboveground and belowground. The highest output appears to have been attained during the period from 1880 to 1884, when the output per person employed aboveground and belowground was 339·4 tons, and per person

TABLE VIII.—NUMBER OF DEATHS FROM DIFFERENT CAUSES OF ACCIDENTS IN AND ABOUT THE MINES OF THE YORKSHIRE MINES-INSPECTION DISTRICT, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp or Coal-dust.	Falls of Side and Roof.	Shafts.	Miscellaneous Underground	On Surface.	Total.	Deaths per 1,000,000 Tons of Mineral Raised.	Persons employed Aboveground and Underground	Tons of Mineral Raised.
1A.—1851.									
Average per annum	71	17	12	3	3	106	15·70*	23,500	6,750,000*
Ratio per 1,000 Persons employed Aboveground and Underground...	3·02	0·72	0·51	0·13	0·13	4·51	...	...	...
Do. do. per cent.	66·9	16·0	11·3	2·9	2·9	100·0	...	...	...
1.—1851-1855.									
Average per annum	27·4	19·8	14·0	6·0	2·4	69·6	...	...	...
Do. do. per cent.	39·4	28·4	20·1	8·6	3·5	100·0	..	...	...
2.—1860-1864.									
Average per annum	20·0	25·8	13·2	6·0	1·4	66·4	7·26*	...	9,141,600*
Do. do. per cent.	30·1	38·9	19·9	9·0	2·1	100·0	...	...	...
2A.—1864.									
Average per aunum	6	27	15	3	4	55	5·91*	34,500	9,300,000*
Ratio per 1,000 Persons employed Aboveground and Underground...	0·17	0·78	0·44	0·09	0·11	1·59	...	...	...
Do. do. per cent.	10·9	49·1	27·3	5·4	7·3	100·0	...	...	...
3.—1870-1874.									
Average per annum	21·6	46·6	13·4	15·8	9·6	107·0	7·64	49,279	13,990,810
Ratio per 1,000 Persons employed Aboveground and Underground...	0·44	0·95	0·27	0·32	0·19	2·17	...	...	...
Do. do. per cent.	20·2	43·6	12·5	14·8	8·9	100·0	...	...	...
4.—1880-1884.									
Average per annum	8·2	53·4	7·0	17·4	10·4	96·4	5·03	62,102	19,142,229
Ratio per 1,000 Persons employed Aboveground and Underground...	0·13	0·86	0·11	0·28	0·17	1·55	...	...	...
Do do. per cent.	8·5	55·4	7·3	18·0	10·8	100·0	...	...	...
5.—1890-1894.									
Average per annum	30·0	45·6	10·0	22·0	15·4	123·0	5·58	86,582	22,039,056
Ratio per 1,000 Persons employed Aboveground and Underground...	0·35	0·53	0·11	0·25	0·18	1·42	...	...	...
Do do. per cent.	24·4	37·1	8·1	17·9	12·5	100·0	...	...	...
6.—1895-1899.									
Average per annum	14·8	42·8	4·6	24·0	15·8	102·0	4·03	91,008	25,290,940
Ratio per 1,000 Persons employed Aboveground and Underground...	0·16	0·47	0·05	0·27	0·17	1·12	..	...	...
Do. do. per cent.	14·5	42·0	4·5	23·5	15·5	100·0	...	...	...

* Coal alone.

employed underground, 420·1 tons. Last year, the output per person employed aboveground and belowground was 320 tons, and underground 400 tons (Table X.).

TABLE IX.—COMPARISONS OF THE RATIOS OF DEATHS FROM DIFFERENT CAUSES OF ACCIDENTS IN AND ABOUT THE MINES OF THE YORKSHIRE MINES-INSPECTION DISTRICT, UNDER THE COAL-MINES REGULATION ACTS.

PERIODS.	Explosions of Fire-damp or Coal-dust.	Falls of Side and Roof.	Shafts.	Miscellaneous Underground.	On Surface	Total.	Deaths per 1,000,000 Tons of Mineral Raised.
2A.—1864 ...	0·17	0·78	0·44	0·09	0·11	1·59	5·91*
6.—1895-1899 ...	0·16	0·47	0·05	0·27	0·17	1·12	4·03
Percentage	93·1	60·1	11·5	302·2	149·1	70·3	68·1
3.—1870-1874 ...	0·44	0·95	0·27	0·32	0·19	2·17	7·64
6.—1895-1899 ...	0·16	0·47	0·05	0·27	0·17	1·12	4·03
Percentage	36·9	49·7	18·4	82·1	89·1	51·6	53·0

* Coal alone.

TABLE X.—SHEWING THE AVERAGE OUTPUT OF COAL, ETC.; AVERAGE NUMBER OF PERSONS EMPLOYED UNDERGROUND; AVERAGE OUTPUT PER PERSON EMPLOYED UNDERGROUND; AVERAGE NUMBER OF PERSONS EMPLOYED ABOVEGROUND AND UNDERGROUND; AND THE AVERAGE OUTPUT PER PERSON SO EMPLOYED, FROM 1851 TO 1899, IN ALTERNATE QUINQUENNIAL PERIODS, FOR GREAT BRITAIN AND IRELAND.

PERIODS.	Mineral raised per annum.	Number of Persons Employed Underground per annum.	Mineral raised per annum per Person Employed Underground.	No. of Persons Employed Aboveground and Underground per annum.	Mineral raised per Person Employed Aboveground and Underground per annum.
	Tons.		Tons.		Tons.
1.—1851-1855	58,222,894*	?	?	229,468	253·7
2.—1860-1864	86,627,076*	?	?	291,172	297·5
3.—1870-1874	127,492,781	?	?	438,568	290·7
4.—1880-1884	171,079,381	407,177	420·1	503,941	339·4
5.—1890-1894	191,789,652	542,326	353·6	674,450	284·3
6.—1895-1899	214,773,656	566,020	379·4	704,816	304·7
6A.—1899	233,319,084	583,009	400·0	729,009	320·0
COMPARISON OF DIFFERENT PERIODS.					
1.—1851-1855	58,222,894*	?	?	229,468	253·7
6.—1895-1899	214,773,656	566,020	379·4	704,816	304·7
Increase per cent.	368	?	?	307	120

NOTA BENE.—From 1851 to 1864, the particulars are taken from *Hunt's Mineral Statistics*; and subsequent to 1864 from the Reports of H.M. Inspectors of Mines. The minerals raised include coal only prior to 1862; subsequent to 1862, and up to 1871, coal and coal-measures ironstone; and subsequent to 1872, all the minerals from mines under the Coal-mines Regulation Acts. After 1890, the persons employed aboveground and underground include those employed on branch railways, and those engaged in coking and washing coal, numbering 19,147 persons in 1890.

* Coal alone.

Table XI. shews the output of coal, etc., in the Yorkshire mines-inspection district from 1851.

If we consider the factors affecting the output per person employed, these results are not unsatisfactory. Primarily, the state of trade, increasing the number of days worked per annum; the hours worked per day; the profitableness of the labour or amount of earnings, as men invariably work less as their earnings increase; the influx of less skilled labour; and the thickness of the seams or rather the thinness of the seams, will also affect the output.

TABLE XI.—SHOWING THE AVERAGE OUTPUT OF COAL, ETC.; AVERAGE NUMBER OF PERSONS EMPLOYED UNDERGROUND; AVERAGE OUTPUT PER PERSON EMPLOYED UNDERGROUND; AVERAGE NUMBER OF PERSONS EMPLOYED ABOVEGROUND AND UNDERGROUND; AND THE AVERAGE OUTPUT PER PERSON SO EMPLOYED, FROM 1851 TO 1899, IN ALTERNATE QUINQUENNIAL PERIODS, FOR THE YORKSHIRE MINES-INSPECTION DISTRICT.

PERIODS.	Mineral raised per annum.	Number of Persons Employed Underground per annum.	Mineral raised per annum per Person Employed Underground.	No. of Persons Employed Aboveground and Underground per annum.	Mineral raised per Person Employed Aboveground and Underground per annum.
	Tons.		Tons.		Tons.
1.—1851	6,750,000	?	?	23,500	287·2
2.—1860-1864	9,141,600	?	?	?	?
2A.—1864	9,300,000	?	?	34,500	269·5
3.—1870-1874	13,990,810	?	?	49,279	283·9
3A.—1874	15,266,698	49,735	306·9	62,580	243·9
4.—1880-1884	19,142,229	49,941	383·2	62,102	308·2
5.—1890-1894	22,039,056	69,662	316·3	86,582	254·5
6.—1895-1899	25,290,940	72,584	348·4	91,008	277·8
6A.—1899	27,583,493	74,855	368·0	95,140	289·9
COMPARISON OF DIFFERENT PERIODS.					
1.—1851	6,750,000	?	?	23,500	287·2
6.—1895-1899	25,290,940	72,584	348·4	91,008	277·8
Increase per cent.	374	?	?	387	Decrease

Some of my colleagues have taken a great amount of trouble, and have very kindly enabled me to shew to what extent the thinner seams are now being worked. Table XII. shows the quantity of coal produced from seams of 3 feet and under in thickness. It will be seen that nearly 39 million tons of coal were so obtained during 1899, and this amount forms 17·65 per cent. of the total production of coal (220,085,368 tons) in the United Kingdom. The mines-inspection district from which the largest tonnage was obtained being Durham.

The effect of the working of thinner seams of coal upon the output per person employed underground is clearly shown by Table

XIII., containing the results obtained from the working of thin seams in one of the mines-inspection districts; and also by Table XIV., containing the results kindly supplied to me for several other districts. The average output throughout the United Kingdom during 1899 was 400 tons per person employed underground.

TABLE XII.—ESTIMATED QUANTITY OF COAL OBTAINED FROM SEAMS OF 3 FEET AND UNDER IN THICKNESS.

Mines-inspection District.	Tons.
East Scotland	3,971,570
West Scotland	4,604,600
Newcastle-upon-Tyne	4,406,580
Durham	8,135,261
Yorkshire	5,188,000
Manchester...	3,053,307
Liverpool	2,572,776
Midland	1,067,000
North Staffordshire	481,759
South Staffordshire	50,000*
South-Western	3,472,730
South Wales...	1,898,142
TOTAL	38,901,725

* Estimated quantity.

TABLE XIII.—SHEWING THE PRODUCTION OF COAL FROM SEAMS UNDER 36 INCHES IN THICKNESS IN A MINES-INSPECTION DISTRICT.

Thicknesses of Seams.	Coal.	Output of Coal per Person Employed Underground.
	Tons.	Tons.
12 Inches and under	14,939	177·8
Over 12 Inches and up to 18 Inches ...	277,093	269·4
Over 18 Inches and up to 24 Inches ...	568,684	315·2
Over 24 Inches and up to 30 Inches ...	736,194	344·5
Over 30 Inches and up to 36 Inches ...	1,456,397	390·2
TOTAL	3,053,307	

The highest output concerning which I have been able to obtain information shows the following magnificent result:—896 persons employed underground produced 680,000 tons per annum, or 758·9 tons per person employed underground, from a seam 5 feet 3 inches thick.

The enormous increase in the production of coal, bearing as it does on the probable duration of our coal-supply, has led to much speculation, and many have been the prophecies and estimates as to its probable duration. The proved inaccuracy of many of these

estimates should lead to greater care being taken in estimating the amount of available coal and its probable duration. It is certain that further discoveries of extensions of our coal-fields will be made. The immense amount of coal proved by the borings to the east of Doncaster is only one illustration, and many could be given. In south-west Lancashire, the time is fast approaching when the extension of that coal-field under the New Red Sandstone and Permian Measures will be proved. The results of two of the bore-holes made in Kent prove that a coal-field exists there: it may be a small, or a series of small, coal-fields. Undoubtedly, however, large expenditure of capital and the utmost skill will be required to win the Kentish coal.

TABLE XIV.—SHEWING THE PRODUCTION OF COAL FROM SEAMS UNDER 36 INCHES IN THICKNESS IN OTHER MINES-INSPECTION DISTRICTS.

Thicknesses of Seams.	Persons Employed Underground.	Coal.	Output of Coal per Person Employed Underground.
Inches		Tons.	Tons.
13 to 26	2,378	700,128	294·4
15 to 28	1,344	389,664	289·9
24 to 36	650	288,000	443·0*
26	45	21,600	480·0*

* The collier is wholly employed in hewing coal.

TABLE XV.—SHEWING THE COSTS OF WORKING SEAMS LESS THAN 3 FEET THICK IN GREAT BRITAIN.

	Thicknesses of Seams.	Output of Coal per Collier per day.	Price per ton paid to Collier.	Cost of Underground Wages.
	Inches.	Tons	s. d. s. d.	s. d. s. d.
I. SERIES—	Up to 12	0·5 to 1·7	4 0 to 7 6	7 0 to 9 6
	12 to 18	1·0 to 2·5	5 0 to 5 0	3 4 to 7 6
	18 to 24	1·2 to 2·5	2 11 to 3 11	3 9 to 6 4
	24 to 30	1·5 to 3·2	2 2 to 4 1	3 6 to 5 6
	30 to 36	2·0 to 3·2	2 7 to 3 10	3 6 to 5 6
II. SERIES*—	13 to 36	1·5 to 4·5	1 6 to 4 4	2 7 to 5 8
III. SERIES†—	24 to 36	3·0 to 4·0	1 0 to 1 10	3 4 to 3 7
IV. SERIES‡—	18 to 28	2·0 to 3·9	1 1 to 2 0	5 3 to 5 10

* In this series, the lowest output of 1·5 tons of coal is wrought from a seam 17 inches thick, and the highest of 4·5 tons from a seam 26 inches thick. In one instance, 3·5 tons per man is worked from a seam 13 inches thick, whereas in a seam 30 inches thick only 1·65 tons was obtained per collier.

† In this series, the output per collier per day varies with the thickness, being 3 tons in a 24 inches seam, and 4 tons in a 36 inches seam. In this series, the collier is solely employed in getting coal, having no other labour to perform. It is noteworthy that the highest output per collier per day is obtained from this series.

‡ In this series, two thin seams, 18 inches thick, produce 3·65 tons of coal per collier, while a seam 27 inches thick only yields 2·5 tons.

To prolong the duration of our coal-supply by the imposition of duties on exported coal, is a very doubtful solution of the question, and many difficulties arise during its consideration.

It is certain that the working of our thinner seams and of our deeper seams will be considerably extended. It is recognized that the thinner seams will be more expensive to work, and this is shown by the results recorded in Table XV., supplied from actual working collieries.

Thin seams are extensively worked on the Continent, and in the Pas-de-Calais (France), and notwithstanding the high wages now prevailing, the cost of working a ton of coal at a properly managed colliery, including general expenses, interest, and sinking fund upon the capital employed, varies from 5s. in a seam 4 feet thick to 7s. in a seam 2 feet thick, as recorded in Table XVI.

TABLE XVI.—SHEWING THE COSTS OF WORKING SEAMS LESS THAN 47 INCHES THICK IN THE PAS-DE-CALAIS, FRANCE.

Thicknesses of Seams. Inches.	Cost of Underground Wages. s.	d.
23 to 26	6	11
29	6	6
31	6	2
47	5	0

* The cost of timbering averages 6½d. per ton.

After careful examination of the results obtained from the working of thin seams in this country, it may be stated generally that actual trial is necessary to ascertain whether or not a given seam can be profitably worked. Profitable results have been obtained from working a seam 20 inches thick, dipping 1 in 3½, at a depth of 2,100 feet below the surface. In another case, a seam, also 20 inches thick, is of such excellent quality and so easily worked, that there is no difficulty in obtaining a supply of men, and there is a constant demand in the market for the coal.

It has been repeatedly stated that the cost of working thin seams will be considerably reduced by the introduction of coal-cutting machinery. Some of my colleagues have, at infinite trouble, enabled me to obtain a census of the number of coal-cutting machines at work in each of the mines-inspection districts of this country during the year 1899. The results are summarized in Table XVII., which shows that more machines are at work in the Yorkshire than in any other district. There are 83 machines working in Yorkshire, of which 81 are disc-machines and 2 bar-machines. The estimated quantity of coal, cut by 254 machines

in 1899, was 3,538,408 tons or 1·6 per cent. of the total production of 220,085,368 tons.

TABLE XVII.—NUMBER OF COAL-CUTTING MACHINES AT WORK AND ESTIMATED PRODUCTION OF COAL IN THE SEVERAL MINES-INSPECTION DISTRICTS.

Mines-inspection Districts.	Coal-cutting Machines.		Estimated Quantity of Coal Cut by Machinery.
	Compressed Air.	Electricity.	
	No.	No.	Tons.
East Scotland	19	1	400,000
West Scotland	12	...	232,500
Newcastle-upon-Tyne	14	...	280,000
Durham	5	3	57,837
Yorkshire	67	16	1,046,941
Manchester	7	6	86,580
Liverpool	34	2	486,856
Midland	25	23	783,000
North Staffordshire	5	1	43,156
South Staffordshire	...	5	56,960
South Western	2	...	15,392
South Wales	7	...	49,186
Totals	197	57	3,538,408

Machines are now at work that have been working in the same seam for the past 10 years, and others for 8 years, 6 years, etc. It is evident that machinery can be applied to the working of certain seams; and further the machine must be made to suit the seam, as one cannot expect that a machine will work under varying conditions in any seam. Many proofs have been submitted to me showing that excellent results are being obtained, including increased output, increased percentages of large coal, reduced costs of production, and increased earnings by the workers. One mining-engineer states that the daily earnings which by hand-labour amounted to 7s. per day, had been increased by the use of machines to 9s. per day, and the production of coal increased from 2 tons 17 cwts. to 5 tons 13 cwts.; and that 500,000 tons of coal were got by machine and 369,000 tons by hand, per reported accident.

It is stated that if electricians would grapple with and overcome the question of danger, which many engineers associate with the use of electric coal-cutters at the working-faces, there would be a marked increase in their use. It is unfortunate that the question of safety cannot be satisfactorily settled. Some engineers say that electric sparks will ignite gas, while others allege the contrary. Some allege that an air-and-gas-tight cover may be de-

pended upon to prevent ignition; and others say that however tight the cover may be before commencing work, the vibration of the machine when running tends to destroy the seal. Polyphase current is held by some to be the perfect remedy, but others doubt it. In the past it has oftentimes required a disaster to establish the necessity for precautions, and it would be lamentable to await such a proof in the case of electric motors.

Although the conditions are vastly different from those prevailing in this country, it is interesting to notice what is being done in the United States of America. Mr. Parker, statistician of the U.S. Geological Survey reports that in 1899, 43,963,933 tons of coal (23 per cent. of the total production) were cut by 3,125 machines. In 1896, only 1,146 machines were at work, producing 16,424,932 tons of coal, so that there has been an increase of 168 per cent. since that year.

It may be noted that Great Britain has been ousted from its premier position, and the United States of North America now produce the greatest amount of coal of any country in the world, namely 226,500,000 tons. In 1896, the production of the States having coal-cutting machines in use was 115,921,829 tons; and in 1899, the production was 191,144,218 tons, an increase of 65 per cent. Unquestionably this increased production was largely due to the increased use of coal-cutting machines.

The depth at which coal is mined is increasing and the working of deeper seams is becoming more general. It has been stated that the working of deep seams will be much more costly than shallow seams. It may be admitted that some seams will show a higher cost of working, but others may be worked at a slightly increased cost. This is being proved by the working of a seam, 20 inches thick at a depth of 2,100 feet at a cost varying from 4s. 9d. to 5s. per ton for underground wages; the cost of timber being very little more than 1d. a ton.

At a mine, working a seam about 30 inches thick, at depths varying from 750 feet to 2,550 feet, the cost of timber does not exceed 3d. per ton, and the total amount of underground wages lies between 5s. 9d. and 6s. per ton. Very little more timber is used in the deep than in the shallower parts of the mine.

It must be observed that these details of costs are only intended

to convey information to those competent to receive it, the ignorant should remember that the costs given are details only, and do not include the full expense of raising coal.

In working a seam over 5 feet thick from the surface downward to a depth of 3,600 feet, it appears to be necessary to rely

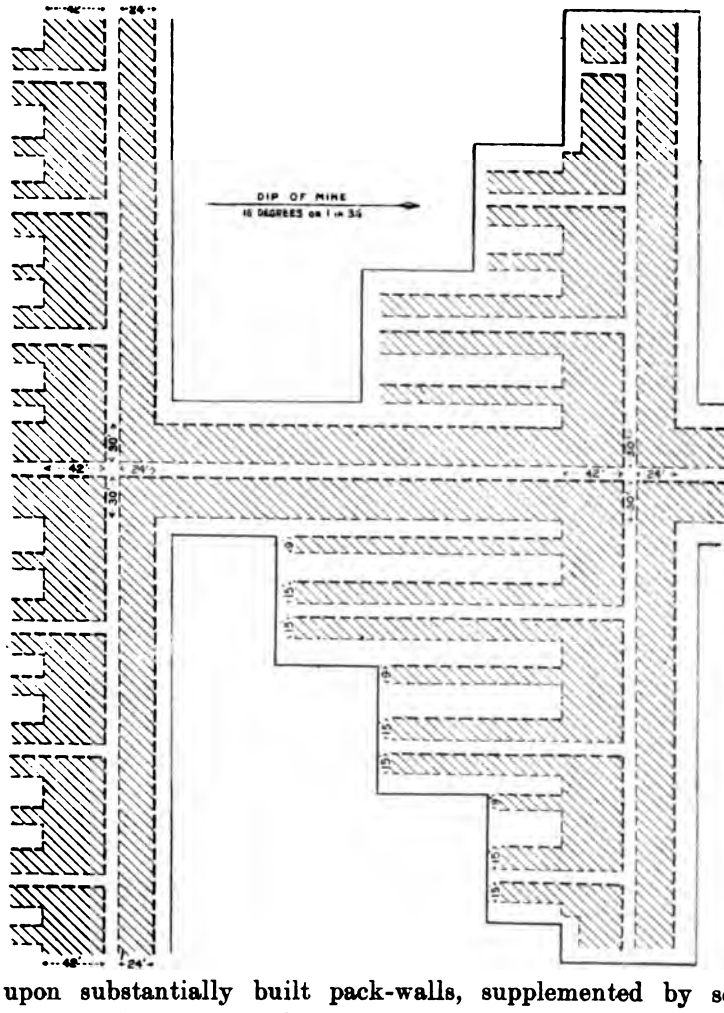


FIG 1.—PLAN OF LONGWALL WORKINGS AT A DEPTH OF 3,600 FEET.
SCALE, 125 FEET TO 1 INCH.

upon substantially built pack-walls, supplemented by square wooden chocks, in preference to timber props or bars. Fig. 1 shows the arrangement of the working-places, and the position of the pack-walls. The working-places are driven 90 feet wide, and if it be required that the faces should advance more quickly, owing to a heavy roof, then the width should be reduced to, say, 60 feet.

Experience of the working of several deep seams lends no support to the theory advanced that increased depth, *per se*, makes a good roof into a bad one. If the form of the working-places be adapted to the increased depth, there can be no great difficulty in sustaining the roof, at a very slight increase in the cost of supporting it. It is impossible to leave other than temporary coal pillars at depths exceeding 3,000 feet. The coal left in pillars will be crushed, and friction developes highly increased temperature in the working-places adjacent to the pillars.

TABLE XVIII.—OBSERVATIONS OF THE HUMIDITY OF THE AIR IN A DEEP MINE.

Time on October 22nd, 1900.	Place.	Thermometers.		Elastic Force of Aqueous Vapour.	Weight of Aqueous Vapour per Cubic Foot of Air.	Relative Humidity: Saturation being 100.
		Dry Bulb.	Wet Bulb.			
p.m.		Degrees	Degrees	Inches.	Grains.	
1.0	Surface	53½	50	0·316	3·55	77
1.35	Bottom of Downcast Shaft	64	58	0·403	4·5	65
1.45	3,600 feet down Engine-brow	71	63	0·464	5·1	61
2.0	5,700 do. do.	79	70½	0·607	6·6	61
2.35	Far end of Workings, 3,600 feet below the Surface...	91	81	0·862	9·0	59

It has been stated that coal won at high temperatures will disintegrate and fall to small pieces after exposure to the lower temperature of the surface; but in several cases brought under my own observation, coal from the deepest seams is stacked, when necessary, without more than the ordinary falling away; and in the working of the coal the usual percentages of round coal may be obtained. Another statement is that the amount of work capable of being performed in deep seams is very limited; and it is doubtless true, that when the ventilation is permitted to become stagnant the men work sluggishly, but if brisk ventilation, good currents, be maintained, the ordinary amount of work will be done. I saw recently, a man almost 69 years of age, at 3 p.m., after working at a depth of 3,600 feet below the surface—he was hale, hearty, active, and showed no indication of undue fatigue or exhaustion; and he told me that he had worked in this mine from 1854, at depths varying from 1,500 to 3,600 feet.

It will probably be found that the amount of humidity in the underground air will affect the capacity to work. The observations recorded in Table XVIII. were taken in a deep mine, and show its temperature and hygrometric conditions. The highest

temperature was 91° Fahr. near a working-face and in a return-airway from deeper workings. The air at the surface had a humidity of 77 per cent., and at the far end of the workings, of 59 per cent.: the load of aqueous vapour having increased from 3·55 grains to 9 grains per cubic foot.

There is no profession or occupation associated with so many of the sciences as that of the mining engineer, or in which the field for the exercise of his intelligence is so constantly being enlarged. There can be no standing still, and if any one attempts it, he is speedily left behind. I trust that the Midland Institute of Mining, Civil and Mechanical Engineers may always be in the van of progress, and that the members will unite in the carrying forward of its banner, so that next year and for very many years to come its present position shall be fully maintained.

Mr. C. E. Rhodes, in proposing a vote of thanks, said that the President and himself started their professional careers some 30 years ago, the President as H.M. inspector of mines and he (Mr. Rhodes) as a colliery-manager. Since that date, the difficulties of colliery-management had been considerably increased. The President had also probably found that the difficulties in connection with his position as one of H.M. inspectors of mines had also increased, but he believed that the President had received increased assistance from colliery-managers. He ventured to say that no system of mines-inspection could bring about successful results without the cordial co-operation of H.M. inspectors of mines on the one hand and of colliery-managers on the other. It was absolutely impossible to suppose that, if one of H.M. inspectors of mines went to a colliery in a draconic way, and treated the manager as his subordinate, mutual confidence would ensue. In this district, if a manager had been in difficulties, H.M. inspectors of mines had endeavoured to help him to solve his difficulties, and to adopt measures for the saving of life. Mr. Gerrard had left the Yorkshire district for a position which involved a vast increase in responsibility, and it was a great compliment to the Midland Institute that he (the President) should take upon himself the office of President, and endeavour further to promote the interests of South Yorkshire.

He hoped that the President's address would stimulate the members of the Midland Institute of Mining, Civil and Mechanical

Engineers. A neighbouring institute proposed to change its name and become the Midland Counties Institution of Engineers. The Institute was founded to improve the condition of miners and mining, and there should be no jealousy between one district and another. He trusted that their Institute would maintain its influence; the members should put their shoulders to the wheel, and there would soon be an enlarged membership under the presidency of Mr. Gerrard, whose presence would be a rallying point.

The President stated that the earlier inspectors of mines were men of vast experience and practical knowledge, but he ventured to say that their President had equally vast experience and practical knowledge. He was glad to welcome the President amongst them, and had great pleasure in proposing a cordial vote of thanks to the President for his address.

Mr. W. H. CHAMBERS, in rising to second the proposal of a vote of thanks to the President for his admirable address, said that the members were greatly honoured by Mr. Gerrard accepting the presidency and maintaining his interest in the Midland Institute of Mining, Civil and Mechanical Engineers. Mr. Gerrard had many and multifarious duties connected with his office of H.M. inspector of mines, and he thought that the address which had been given to the members that day, showed that Mr. Gerrard was well worthy of being classed with the earlier inspectors of mines referred to in his address. None of them possessed better knowledge and greater intimacy with mining engineering, or had taken greater care as to the safety and proper working of mines, than their President.

The vote of thanks was warmly approved.

The PRESIDENT (Mr. John Gerrard), replying to the vote of thanks, said that he was pleased to be with them. He would do his best to attend all their meetings, and if he could help the Midland Institute or its members in any way he should be amply repaid.

Mr. W. WASHINGTON read the following "Notes on Sinking to the Parkgate Seam at Mitchell Main Colliery":—

NOTES ON SINKING TO THE PARKGATE SEAM AT MITCHELL MAIN COLLIERY.

By W. WASHINGTON.

The Mitchell Main Colliery Company having decided to sink from the Barnsley seam to the Parkgate seam, it was arranged that this work should be carried out without in any way interfering with the drawing of coal from the Barnsley seam.

Downcast Shaft.—The downcast and drawing shaft, 921 feet deep to the Barnsley seam, was considered most suitable for commencing the sinking operations.

To enable the bottom of the sump to be taken out, without interfering with the drawing of coal, it was necessary to commence the deepening of the shaft at a lower level. There is a 30 feet downthrow fault close to the shaft, and, as the travelling-road in the Barnsley seam goes down this fault, a drift was turned out at a convenient point, driven directly under the downcast shaft, and terminated about 18 feet below the bottom of the sump. A rise-staple was put through to the sump, and then the enlargement to the full diameter of the shaft was commenced: the staple acting as a shoot for the delivery of all débris, which were removed through the drift. The whole of this work was carried out during the night-shift, as, until this widening had been completed, it was impossible to get the girders (mentioned hereafter) into position for the permanent closing of the sump (Figs. 1 and 3, Plate IV.).

The diameter of the shaft is 13½ feet, but, from the bottom of the sump at the Barnsley seam to the level of the drift and landing for the sinking-débris, the diameter was increased to 14½ feet in order to give better facilities for banking purposes. The shaft was next sunk about 10 feet below the level of the drift; here a bricking-ring was inserted, the brickwork was carried upwards to the bottom of the sump, the drift-arches built, and a water-crib inserted above the arches to drain any sipings that might occur.

During the progress of this work, the winding-engine for the sinking was being erected on the surface. This engine has two cylinders, 20 inches in diameter by 3 feet stroke, fitted with a drum 5 feet in diameter, and supplied with steam at a pressure of 60 pounds per square inch at the boilers. The single winding-pulley was fixed on the headgear used for winding from the Barnsley seam, so as to allow the sinking-rope to run between the central conductors, which are spaced 18 inches apart. This rope was a locked-coil, $\frac{7}{8}$ inch in diameter, and the total depth from the surface to the Parkgate seam was 1,722 feet. The trunks weighed 4 cwts., with a carrying capacity of 10 cwts. (Fig. 2, Plate IV.).

The next matter was to pass the winding-rope down through the sump, and to make the latter so secure that no possible accident in the winding-shaft could break through upon the men engaged in sinking to the Parkgate seam. As it was most important to have as much head-room as possible above the banking-platform in the drift, to the point where the detaching-hook would disengage, the weights of the wire-rope conductors, which were suspended below the framework, CD, were re-hung between the two frameworks, AB and CD (Figs. 3 and 4, Plate IV.). The frame AB, where the Barnsley fallers are fixed, is constructed of timber, 16 inches square, covered with wooden planking, 7 inches thick (Figs. 4 and 5). The frame, CD, used for steadying the wire-rope conductors, is made of baulks, 20 inches square, and is strengthened by cross-pieces, 12 inches square, bolted to it. On these baulks, the detaching-bell of the disengaging-hook was fixed (Figs. 4 and 6). To increase the strength, girders, 10 inches web and 5 inches wide, double-flanged, were built into the sides of the shaft, below the frame, CD, and were fixed 9 inches apart, the middle girders being 16 inches apart so as to allow for the passage of the sinking-rope. On the top of these girders, Norway timber, 6 inches square, was laid at right angles, and carefully sawn to fit and cover the entire area of the shaft, except a hole of sufficient diameter for the passage of the winding-rope and detaching-hook (Figs. 4 and 7). There was a height of 24 feet from the banking-platform to the detaching-bell. Figs. 8 and 9 (Plate IV.) shews the arrangements that were made for banking the sinking-débris at the drift-level, and they were found to work satisfactorily and more economically than the trolley-system.

About 20 feet below the banking-platform, a small heading was driven in the Stone coal-seam to the upcast shaft, the sump of which was sunk 60 feet below the Barnsley seam. This heading was bricked (with a barrel arch) and was used as the return air-way for the sinking-shaft. The air for the shaft was conducted through light wrought-iron pipes, 18 inches in diameter, and secured every 9 feet (Fig. 3).

After this work had been completed, regular sinking commenced, on December 21st, 1898, and the Parkgate seam was reached on June 12th, 1899.

The débris from the sinking were banked at the level of the drift, and drawn by horses to the road at the low side of the fault, from whence they were hauled up to the Barnsley seam and drawn to the surface by a small engine on the surface, working a rope passing down the upcast shaft.

After December 21st, 1898, the sinking proceeded day and night. The work was carried on with electric lights, a cluster of 5 lamps of 16 candle-power being swung in the shaft.

The actual sinking possessed no features of special interest: just below the Swallow-wood seam, a strong outburst of gas occurred and delayed the sinking operation for 6 or 8 shifts, and it was accompanied by a feeder of water, equal to about 200 gallons per hour. These outbursts came from a fault, which entered the shaft about 180 feet below the Barnsley seam, and left the shaft on the other side at 282 feet. The flow of gas ceased before the fault was passed through, and the feeder of water soon became unappreciable.

Upcast Shaft.—In the upcast shaft, although there was no coal-drawing, there was the risk of sinking below steam-pipes and water-mains, the latter being under a pressure of 500 pounds to the square inch, and it was thought advisable to minimize this risk as much as possible. Scaffolding and girders were fixed, in a way similar to those in the downcast shaft, at the floor-level of the pumping-engine house, so that if one of the water-pipes were burst, all the water would flow through the water-drift and leave the workmen in safety in the sinking-pit. The winding-rope was passed through a strong pipe in the centre of the scaffold, and the ventilating current was carried through two wrought-iron tubes,

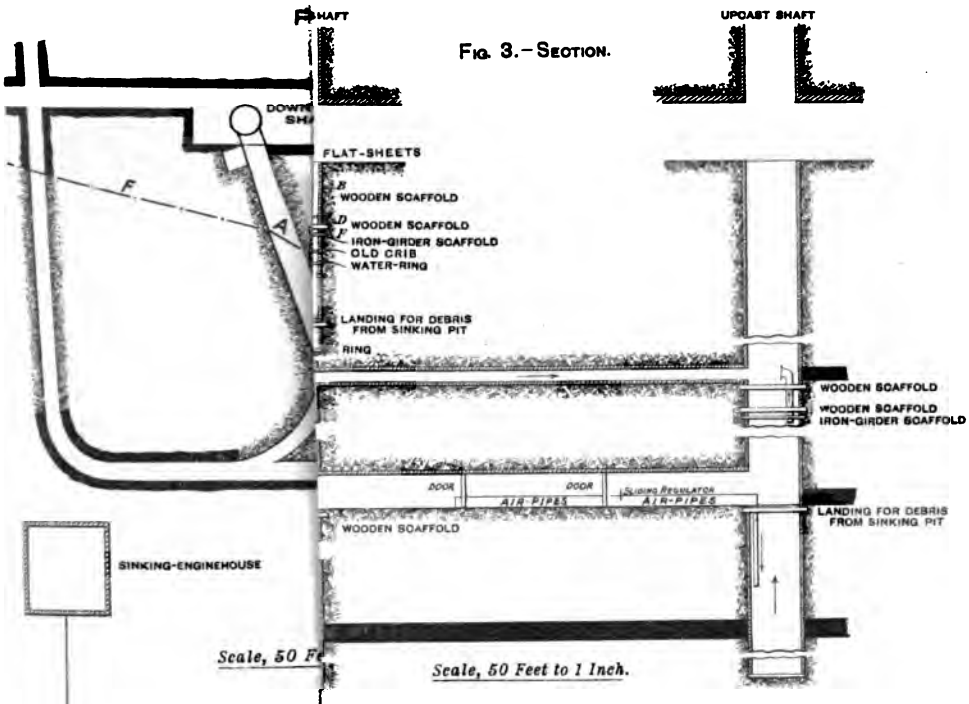


FIG. 3.—SECTION.

FIG. 4.—SECTION.

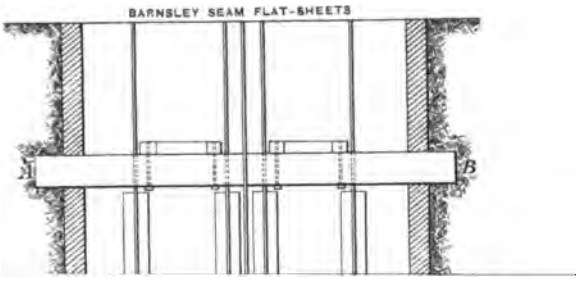


FIG. 2.—PLAN OF SURFAC

each 2 feet in diameter, with double openings at right angles to the axes of the pipes (Fig. 3, Plate IV.).

The depth below the bottom of the sump and the Swallow-wood seam is 105 feet, the débris in this preliminary sinking, owing to the shaft not being used for drawing purposes, were sent direct to the Barnsley seam-level, and thence to the surface up the drawing-shaft. While this work was proceeding, a heading was driven in the Swallow-wood seam from the downcast shaft, 9 feet wide by 6 feet high, to the upcast shaft. In this heading, two pairs of doors were inserted, and the intake air was carried by means of ventilating pipes, 18 inches in diameter, passed through the trap-doors, and they were carried downward as the sinking advanced, similar to those in the downcast shaft (Fig. 3, Plate IV.).

A banking-platform was erected similar to the one used in the downcast shaft (Figs. 8 and 9, Plate IV.), and from this point all the débris were conveyed through the Swallow-wood heading to the downcast shaft, where a chair and temporary guides were inserted from the Parkgate seam to the level of the Barnsley seam. The landing at the Swallow-wood seam in the downcast shaft consisted of a single door, which dropped between the two wire-rope conductors, while the chair rested, the rest of the shaft being closed, with the exception of a scale of air required for ventilation (Fig. 3, Plate IV.).

The sinking of the upcast shaft was commenced on January 3rd, 1900, and the Parkgate seam was reached on June 5th, 1900.

The winding-engine, working from the surface, had a single cylinder, 18 inches in diameter by 3 feet stroke, fitted with a drum 4½ feet in diameter, and geared 4 to 1.

Both shafts are lined with brickwork, 9 inches thick. Gelignite and high-tension detonators were used, the shots being fired by the current taken from the electric-light cables. A special reel was used, so that the electric lights could be raised or lowered rapidly and without extinguishing them.

The sinking of these shafts was accomplished without accident.

Mr. H. B. Nash, in proposing a vote of thanks to Mr. Washington for his paper, said that it contained much useful information, and many of the members would be able to utilize the arrangements described in the paper.

Mr. J. R. ROBINSON-WILSON, in seconding the motion, said that he had had an opportunity of seeing the progress of the sinkings, and the arrangements were admirable in every detail. Moreover, the work had been carried out in an able manner without a single accident or loss of life.

The motion was unanimously approved.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,
FEBRUARY 6TH, 1901.

MR. JAMES T. FORGIE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. JAMES CRAWFORD, Barblues, Plains, Airdrie.

Mr. ARCHIBALD KNOX BROWN, c/o Messrs. Oxley & Company, 31, Lombard Street, London, E.C.

Mr. THOMAS TURNER, c/o Messrs. Andrew Barclay, Sons & Company, Limited, Kilmarnock.

Mr. CHARLES WALKER, Glespin Colliery, Douglas.

STUDENT—

Mr. WILLIAM JARVIE, Park Place, Bothwell.

Office-bearers for the session 1901-1902 were nominated.

DISCUSSION OF MR. H. M. CADELL'S PAPER ON "AN INDIAN COLLIERY AND ITS MINERS."*

The PRESIDENT moved a vote of thanks to Mr. H. M. Cadell for his paper, and the resolution was cordially approved.

DISCUSSION OF MR: ROBERT MARTIN'S PAPER ON "AN ORDINARY MINER'S BORING-MACHINE ADAPTED FOR BORING AGAINST WASTES."†

Mr. JAMES BAIN (Alloa) said that the machine described by Mr. Martin was constructed on lines similar to one already

* *Trans. Inst. M.E.*, 1900, vol. xix., page 60; and vol. xx., page 46.

† *Ibid.*, vol. xix., page 69.

described by Mr. Robert McLaren.* The machine described by Mr. McLaren was automatic, and was fitted with a double set of plunger-pumps, which forced the water to the point of the drill to clear away borings. So far as he (Mr. Bain) could see, the machine described by Mr. McLaren, and invented by Mr. Hunter, which had been working for the past 9 or 10 years, was just as easy of application as Mr. Martin's, as from the description it was apparent that the machine was not self-acting, but depended on a small pump being driven by a second workman for the purpose of forcing water to the point of the drill to clear away the borings, and this certainly could not be so efficient as a machine which worked the pump automatically along with the drill.

Mr. GEORGE L. KERR (Glasgow) said that the drill described by Mr. Martin very closely resembled Mr. Mitchell's drill in use at various collieries. The principle on which both were constructed and wrought was practically the same, but Mr. Martin's application seemed handier. The drill, described by Mr. McLaren and used at some collieries in Fifeshire, was practically the same as Mr. Mitchell's, but the method of advancing the machine as the boring proceeded was somewhat different. In the machine described by Mr. McLaren, it is made to advance by means of a weight-and-pulley, while Mr. Mitchell's machine is advanced by means of a ratchet, like an ordinary miner's drill.†

Mr. J. B. ATKINSON (H.M. Inspector of Mines, Glasgow) said that there was one point in connection with the use of these drills which ought to be kept well in view. No. 13 General Rule of the Coal-mines Regulation Act, referring to boring against wastes, provided that when within 120 feet of a place "likely to contain a dangerous accumulation of water" the place should not be more than 8 feet wide. If by the application of this machine a workman could drill from a longwall face for 120 feet, that might be taken to prove that he was not within 120 feet of the water, and the longwall might be continued. He did not think that it was advisable or desirable to attempt to prove water from a longwall working.

The PRESIDENT (Mr. J. T. Forgie) remarked that Mr. Atkinson, in making that statement, had simply referred to the safety

* *Trans. M. I. Scotland*, 1891, vol. xiii., page 81. † *Ibid.*, vol. xiii., page 82.

of the men whilst boring. In many instances he thought that 120 feet would be quite insufficient to protect a colliery with a very large body of waste-water standing before it. He knew in one case that provision had to be made for a barrier of 350 to 400 feet being left, to prevent water from percolating through. In the Pyotshaw and Splint coal-seams, the water had been proved to come through very large, thick barriers, and for the protection of the colliery from additional water, not so much as for the protection of the miner, thicker barriers must be left. It seemed to him (Mr. Forgie) that it would be a simple matter to apply the pump to the same mechanism as that which drove the drill instead of driving the pump separately.

Mr. J. B. Atkinson asked whether there was any likelihood in long holes of the bore getting out of the coal and going into the pavement or roof.

Mr. R. Broom (Bargeddie) said that he had been using the Mitchell drill in the Kiltongue seam, boring holes 140 feet long, for the purpose of running off some waste-water. He might mention that the last 6 feet was easily bored, because the machine was boring very clean. If, however, the pumps were not working perfectly, it was impossible to bore properly. He had made some twenty or thirty holes in the Kiltongue seam.

Mr. J. B. Atkinson asked whether any of the holes had caught the roof or pavement.

Mr. R. Broom replied in the negative, and explained that the Kiltongue seam was 6 feet thick.

The President said it was a wellknown fact that a vertical bore-hole often went a long way from the vertical position. He remembered boring for waste-water in shale, 15 inches thick, underneath ironstone. The bore was commenced 6 inches from the top of the shale, and the distance bored was 74 feet at an inclination of about 1 in 7. It was worthy of note that at the end of the 74 feet the bore had only changed its position by 2 inches in the shale.

Mr. James Bain said that, in the Alloa collieries, they had been boring holes from 200 to 235 feet long, in a coal-seam 3 feet thick. The inclination of the seam varied from 1 in 4 to 1 in 5.

The discussion was then closed, a hearty vote of thanks being given to Mr. Martin for his paper.

DISCUSSION OF MR DANIEL BURNS'S PAPER ON THE "WEIGHT OF WINDING-DRUMS FOR DEEP SHAFTS."*

Mr. GEORGE A. MITCHELL (Glasgow) wrote that Mr. Burns did not attempt to make an exact enquiry into the subject, and the figures which he supplied were perhaps better as an illustration than as giving the exact difference in the use of drums of different weights. The weight of the moving mass to be accelerated, seems to be the weight of the drum *plus* that of the useful load, and not the weight of the drum only; and the rate of acceleration of this mass depends on the power applied to it. The acceleration may be at a quicker or slower rate than the retardation which is due to the gravity of the useful load. Naturally, the greater the power of the winding-engine, the less will be the difference of time in winding due to the heavy drum; for the mass to be accelerated, including as it does the useful load, does not increase in exact proportion to the weight of the drum. The momentum of the drum also depends upon the distribution of the weight as well as on the total weight. He thought that the word "acceleration" would be better omitted after formula (4)† as the time of acceleration was, as he had stated, not necessarily the same as the time of retardation. Instead of referring to the work lost in heating the brake-block‡, it would be better to state that in addition to the loss of 3·49 seconds, there is the extra work done in winding at full power for 33·49 seconds instead of 30 seconds. The work spent in heating does not convey a very clear idea of the amount involved. The paper proves very clearly the advantage of light, as compared with heavy, drums. It is very necessary to go into such details in connexion with similar colliery-appliances, and it is hoped that the example given by Mr. Burns may be followed by other members, and that we may have other papers of a similar kind.

Mr. G. L. KERR (Glasgow) thought that Mr. Burns was correct in taking the time of acceleration and retardation as being

* *Trans. Inst. M.E.*, 1900, vol. xx., page 49.

† *Ibid.*, page 50. ‡ *Ibid.*, page 51.

equal, because if friction be neglected, then the time taken for acceleration and retardation will be the same. Mr. Burns was trying to demonstrate the advantages of a light drum over a heavier one, and was not proposing to establish any relation between the weight of the drum and the size of the winding-engine. Had he endeavoured to do so, then, no doubt, Mr. Mitchell would be right in stating that the useful load should be taken into account. But, following Mr. Mitchell's argument, he thought that the total weight to be set in motion was the weight of the drum *plus* the useful load, together with the weight of the winding-ropes, pulleys, etc. The work required to overcome the resistance of the parts moved by the winding-engine is difficult to calculate exactly; and it is, therefore, necessary to give the winding-engine ample power, and that the weight of the ropes, etc., should be taken into account. The subject of winding-engines and drums was clearly explained in Prof. W. Galloway's *Course of Lectures on Mining*, and in the *Cours d'Exploitation des Mines*, by Mr. Haton de la Goupillière.

The PRESIDENT (Mr. J. T. Forgie) remarked that in building many winding-engines, rule-of-thumb was used in fixing the weights. Heavy drums acted as fly-wheels, and, although they were difficult to start, they were at the same time difficult to stop. In fact, useful brake-power was exerted in stopping them, as well as power that might be applied in a more economical way in starting them. He (Mr. Forgie) had recently put on a balance-rope at one of his collieries, and he had found it to be of considerable advantage in winding. With a limited supply of steam, the pressure of steam at times became low, and they were forced to adopt some method that would assist the engine in lifting away the heavy load; so, after applying the balance-rope, they could lift the cage from the bottom with about 30 pounds of steam, whereas previously 55 to 60 pounds was required. Now, when steam was shut off without a balance-rope, the weight of the rope and the descending cage was greater than the weight of the load, and the tendency was for the engine to run faster at the end of a wind, and tremendous brake-power was required. The very opposite was the case when a balance-rope was applied to the winding-engine.

Mr. J. B. ATKINSON said that the winding-engine at Kelty colliery, which was 1,248 feet deep, was fitted with a balance-

rope and it appeared to work very satisfactorily. Last year, however, the balance-rope had led to a somewhat curious accident; so for a week the balance-rope was not used, and there was a decided diminution in the output.

Mr. G. L. KERR asked whether there was any increase in the wear of the winding-ropes, due to the use of a balance-rope.

The PRESIDENT (Mr. Forgie) said that his balance-rope had been in use for 4 years, and there was no apparent difference in the wear-and-tear of the winding-ropes. The last winding-rope taken off, had worked for 4 years and 3 months, and had wound 350 tons a day. When the balance-rope was put on, the question of danger from such an accident as that which happened at Kelty colliery was very thoroughly considered. Accidents would always happen at collieries, but he did not think that to abolish the balance-rope would be the proper remedy in this case.

The discussion was adjourned.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
OCTOBER 13TH, 1900.

MR. J. G. WEEKS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on September 29th, and that day, and of the Council of The Institution of Mining Engineers.

DEATH OF MR. HENRY AYTON.

The PRESIDENT (Mr. J. G. Weeks), referring to the recent death of Mr. Henry Ayton, said that he had contributed to the *Transactions*, and had always taken great interest in their proceedings. He had invariably been an attentive member of Council, and had furthered in every way the interests of the Institute. He moved that a vote of condolence be sent to Mrs. Ayton, conveying their sincere sympathy with her in the loss that she had sustained.

The vote of condolence was adopted.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. HENRY BARTON. Mining Engineer, Central Bank Chambers, Leeds.

Mr. CHARLES HENRY DAVIS, Consulting Engineer, 99, Cedar Street, New York City, United States of America.

Mr. ROBERT HARVEY GOODWIN, Mining Engineer, c/o Messrs. Bewick, Moreing and Company, Coolgardie, Western Australia.

Mr. PERCY GRAVE, Mining Engineer, Santa Barbara, State of Chihuahua, Mexico.

Mr. HENRY HUMPHRIS, Quarry Manager, Blaenau Festiniog, North Wales.

Mr. FRANK KLEPETKO, Manager of Mines and Reduction-works, Great Falls, Montana, United States of America.

Mr. JOSEPH LANCASTER, Mining Engineer and Mine-manager, 16, Nelson Street, Dalton-in-Furness.

Mr. ROBERT TENNANT WIGHT, Colliery Engineer, Hallbankgate, Milton, Carlisle.

ASSOCIATE MEMBERS—

Mr. P M. BRUTTON, 17, Sandhill, Newcastle-upon-Tyne.

Mr. JOHN JACOBS, Burford, Oxford.

ASSOCIATE—

Mr. JOSEPH MARR, Deputy-overman, Chopwell, Lintz Green, R.S.O., County Durham.

STUDENT—

Mr. JOSEPH HENRY WALKER, Mining Student, 1, Elms North, Sunderland.

Prof. P. P. BEDSON (Durham College of Science) read the following paper by Mr. T. Baker, Johnston Scholar, Durham College of Science, on "The Solvent Action of Pyridine on certain Coals":—

THE SOLVENT ACTION OF PYRIDINE ON CERTAIN COALS.

By T. BAKER, B.Sc.

In a paper read before this Institute by Dr. Bedson, he incidentally referred to the action of pyridine on coal.* Pyridine is a nitrogenous base obtained in the distillation of coal-tar, and that portion of the pyridine bases boiling between 110° and 120° Cent., was used in the following experiments. The object of the work of which this paper is the outcome was to ascertain the nature of the action of pyridine on different coals.

Coals.—The samples of coal acted upon were obtained from the Hutton and Brockwell coal-seams, from collieries in the county of Durham; the samples of anthracite from Yniscedwyn colliery, in South Wales; and the New Zealand coal from the Taupiri colliery, Kimihia, Auckland.

The method of treating the coal was as follows: About 5 grammes of the finely divided coal, were treated with 250 cubic centimetres of pyridine in a Soxhlet extraction-apparatus for 50 hours, after which time the extraction seemed complete. The pyridine solution obtained was red to brown in colour, and in some cases possessed a rich green fluorescence. The pyridine extract was distilled under reduced pressure till the greater part of the pyridine had distilled over. It was then treated with hydrochloric acid to precipitate the dissolved matter, filtered, and the precipitate washed several times with water made slightly acid with hydrochloric acid, finally with water, and afterwards dried in an air-bath at 100° Cent. The residue remaining in the extraction-thimble was dried, to free it from the greater part of the pyridine, washed with water and dried at 100° Cent. The extracts and residues were weighed, and the percentages of each in the original coal calculated.

Although precautions were taken to free the extracts and residues from pyridine, they probably retained a small amount

* *Trans. Inst. M.E.*, 1899, vol. xvi., page 390.

in each case, which may have affected the results given in Table I. The proximate analyses are not altogether comparable, since the coal, extract and residue were each in a different condition at the time of analysis, and the amount taken for analysis was not the same—being very small in the case of the extracts. The results would be affected as shown by Prof. G. Hinrichs, who states that for the same heat, the amount volatilized is greater as the mass heated is smaller and is lowered by drying the coal before analysis. Therefore, the chief information gained from the proximate analysis relates to the varying physical properties of the coke.

The proximate analyses of the original coals were made of undried samples, and those of the residues and extracts from samples dried at 100° Cent. The elementary analyses were all made of samples dried at 100° Cent. and the results calculated on the ash-free sample.

TABLE I.—ANALYSES OF COALS, EXTRACTS AND RESIDUES.

Locality.	No.	Sample.	Proximate Analyses.				Elementary Analyses.				
			Moisture.	Ash.	Volatile Carbon	Fixed Carbon.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur
I.—Hutton Seam	1	Coal	1·35	1·63	30·97	66·05	80·82	4·66	10·81	1·84	1·84
Do.	2	Extract	—	0·05	54·40	45·55	79·37	5·79	10·73	2·66?	1·40
Do.	3	Residue	—	2·80	31·92	65·28	82·06	4·85	9·65	1·78	1·64
II.—Brockwell Seam	4	Coal	0·65	2·90	30·60	65·85	86·59	5 15	5·33	1·67	1·23
Do.	5	Extract	—	—	—	—	77·50	6·16	—	—	—
Do.	6	Residue	—	3·00	30·40	66·60	86·66	4·95	—	—	—
III.—Anthracite*	7	Coal	1·57	1·60	8·23	88·60	92·59	3·55	—	—	0·66
IV.—Coal† ...	8	Coal	15·75	1·65	39·73	42·87	72·45	5·08	20·84	1·15	0·47
Do.	9	Extract	—	—	70·42	29·58	73·72	7·69	—	—	—
Do.	10	Residue	—	2·00	51·67	46·33	70·81	4·63	—	2 11	—

* Ynisedwyn Colliery. † New Zealand.

Anthracite, with over 90 per cent. of carbon, and belonging to class 5 of Gruner's classification of coals, is not sensibly attacked by pyridine. The coal of the Brockwell seam, with 84 per cent. of carbon, yielding a moderately compact coke, and belonging to class 3 of Gruner's classification, has 11·5 per cent. extracted by pyridine. The extract is very rich in volatile matter, and yields a very intumescent coke; while the residue

retained the coking properties of the original coal, to a small extent, although the bulk of the coke was considerably reduced. The coal of the Hutton seam, with 79·5 per cent. of carbon, yielding a caked but friable coke, and belonging to class 2 of Gruner's classification, has 20·4 per cent. extracted. This extract yields a very highly intumescent coke, and is extremely rich in volatile matter, as in the case of the coal of the Brockwell seam. The residue has, however, lost all its coking properties. The New Zealand coal, with 71 per cent. of carbon, yields a pulverulent coke, and seems to belong to a class of coal lower than class 1 of Gruner's classification; about 21·4 per cent. is extracted, but 15·75 per cent. of this consists of water, hence the actual amount extracted is only 5·65 per cent. The residue did not coke, and in this way resembled the original coal; the extract, as in the case of the coals of the Hutton and Brockwell seams, was rich in volatile constituents, and gave a very intumescent coke.

It will be noted that the proportion of hydrogen in the extracts is, in all cases, much higher than in the coal.

It is difficult to draw any conclusions from the results obtained, since the field explored is too limited, but with the treatment of more coals, it may be possible that the use of pyridine would lead to an improved classification and throw light on the present obscure proximate constituents of coal.

Albertite.—The effect of pyridine on a sample of albertite from New Brunswick, and one of Barbados manjak was also tried. The experiments were carried out in the same way as the preceding ones.

The samples of New Brunswick albertite, on analysis, gave the following results:—

Proximate:	Moisture	0·10
	Fixed carbon ...	42·00
	Volatile carbon ...	57·56
	Ash	0·34
	The coke obtained was hard and compact.	
* Elementary:	Carbon	85·27
	Hydrogen	8·31
	Oxygen	2·97
	Nitrogen	3·10
	Sulphur	0·35

* Calculated on ash-free sample.

Two samples of albertite referred to in Dr. Percy's *Metallurgy*,* have the following composition:—

Sample.	Coal Creek, New South Wales.	Nova Scotia.
Carbon	84·13 ...	82·67
Hydrogen	9·23 ...	9·14
Oxygen and nitrogen ...	6·64 ...	8·19

Pyridine had but a slight action on albertite, as compared with that in the above-mentioned coals, and only some 6·3 per cent. was dissolved. The extract was too small for analytical purposes, seemed to coke freely, and in this way resembled the other extracts. The residue resembled very closely the original albertite.

Manjak.—The sample of Barbados manjak, on analysis, gave the following results:—

Proximate:	Moisture	0·30
	Fixed carbon...	36·52
	Volatile carbon	61·60
	Ash	1·58

The manjak melted, and yielded a coke much more voluminous than the volume of the manjak taken.

* Elementary:	Carbon	81·18
	Hydrogen	8·43
	Oxygen...	—
	Nitrogen	1·29

* Calculated on ash-free sample.

Manjak appears to be almost wholly soluble in pyridine, yielding a dark red solution, which possesses a rich green fluorescence.

Manjak and albertite, although resembling each other in outward appearance, differ considerably in their physical properties. Manjak is almost wholly soluble in pyridine, and melts at a temperature much below 100° Cent. Albertite is only slightly attacked by pyridine, and does not coke until a temperature considerably above 100° Cent. is reached. The specific gravity of manjak is 1·08, and it is much softer than albertite, whose specific gravity is 1·10.

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* "Introduction, Refractory Materials and Fuel," 1875, page 331.

Prof. P. P. Bedson thought that pyridine might be utilized to afford some idea of the nature of the coal, and whether it was likely to be of value as a coking coal or not. He would also point out that the results contained in Mr. Baker's paper represented a considerable amount of work and time; and he further expressed the hope that it would be possible to arrange for a further study of this problem which might possibly throw a light on the nature of the compounds entering into the composition of coals.

Mr. W. C. Blackett said that Sir Lowthian Bell had stated that coke made in Simon-Carves coke-ovens proved more "soluble" in the blast-furnace than coke made in bee-hive ovens. Possibly, with the help of pyridine, they might be able to ascertain whether coke made in retort-ovens was more soluble in the blast-furnace.

Prof. Bedson replied that pyridine had a solvent action; but the solubility of coke in the blast-furnace depended on the physical structure of the coke and the action of carbon dioxide on coke at high temperatures.

The President, in moving a vote of thanks to Mr. T. Baker for his paper, said that in this age of progress, they could not tell what results might follow from these experiments, which he trusted would be continued.

The vote of thanks was cordially approved.

Mr. J. L. Hedley (H.M. Inspector of Mines) said that the recent paper written by Mr. Leck and himself described the methods of "Timbering in the Iron Ore-mines of Cumberland and Furness,"* and the same system of timbering existed in many other districts. Dr. C. Le Neve Foster had described a system of timbering in operation at a colliery in France, but that system only differed from that described in his paper, inasmuch as iron bars were used, if necessary, instead of timber, as in Cumberland.

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* *Trans. Inst. M.E.*, 1898, vol. xvi., page 281.

METHODS OF PREVENTING FALLS OF ROOF ADOPTED AT THE COURRIÈRES COLLIERIES.*

By Dr. C. LE NEVE FOSTER.

I should like to call attention to the methods of preventing falls of roof which are now being displayed by the Compagnie des Mines de Houille de Courrières at the Paris Exhibition. From the point of view of an inspector of mines, whose business it is to prevent mine accidents and who knows that the "fall of ground" is by far the deadliest enemy of the miner, I have no hesitation in designating the Courrières exhibit as the most important thing which I saw at Paris.

The Compagnie des Mines de Houille de Courrières is a company working collieries near the town of Lens, in the department of the Pas de Calais, and employing 6,998 persons, of whom 5,794 work belowground. It possesses 44 seams of coal, with a total thickness of 153 feet (46·60 metres). The average thicknesses of the seams of the three kinds of coal worked are respectively: 2 feet 8¼ inches (82 centimetres), 2 feet 10¼ inches (87 centimetres), and 3 feet 7¼ inches (1·10 metres). The annual output is now about 2,000,000 tons. The undertaking is therefore sufficiently extensive to furnish average data of real importance.

The precautionary measures adopted at Courrières consist (1) in systematic timbering, and (2) in supplying each worker at the face with three iron bars, 1§ inches square and 4 feet 3 inches long, and compelling him to make use of these bars to form a sort of temporary shield in advance of the last row of timber-props. When another row of props has been put in, the bars are withdrawn and then driven on in advance beyond the new set of supports. They are placed about 15 to 20 inches apart and fixed securely by wedges. As the work proceeds, the temporary protecting shield must be pushed on; the men are

* *Mines and Quarries: General Report and Statistics for 1899*, page 74.

now so practised that it takes them a very few minutes to knock out the wedges, drive the bars forward, and wedge them up again. About 6,000 bars are in daily use at the Courrières collieries. If they get bent, which not infrequently happens, they can easily be straightened by the smith; on the other hand, they rarely break, because if a great amount of bending indicates an unusual pressure of the roof, additional timber-props are put in. Consequently the consumption of iron bars is trifling.

Figs. 1, 2, 3, 4 and 5 (Plate V.) will explain the Courrières methods, which are simple and effective. I have to thank Mr. Paul Schneider, the vice-president of the company, and Mr. Auguste Lavaurs, the managing director, not only for the drawings from which these figures have been copied, but also for sundry facts and figures concerning their collieries.

TABLE I.—AVERAGE DEATH-RATES FROM FALLS OF GROUND PER 1,000 PERSONS EMPLOYED UNDERGROUND.

Country or Mine.	Periods.		
	1870 to 1879.	1880 to 1889.	1890 to 1899.
United Kingdom †	1·19	1·10	0·79
France ‡	1·10	0·76	0·59*
Courrières ‡	0·76	0·24	0·15

TABLE II.—AVERAGE DEATH-RATE FROM FALLS OF GROUND PER 1,000,000 TONS of MINERAL RAISED.

Country or Mine.	Periods.		
	1870 to 1879.	1880 to 1889.	1890 to 1899.
United Kingdom †	3·24	2·66	2·16
France ‡	4·00	2·75	2·04*
Courrières ‡	3·13	0·70	0·39

* Period 1890 to 1898.

† Mines under the Coal mines Regulation Acts.

‡ Figures taken from a diagram prepared by the Courrières Company for the Paris Exhibition.

The two standards by which the efficacy of the Courrières methods may be gauged are the mortality rates from falls (1) per 1,000 persons employed underground, and (2) per 1,000,000 tons of mineral extracted. The comparisons of the Courrières death-rates with those of France and England are shown numerically by Tables I. and II.

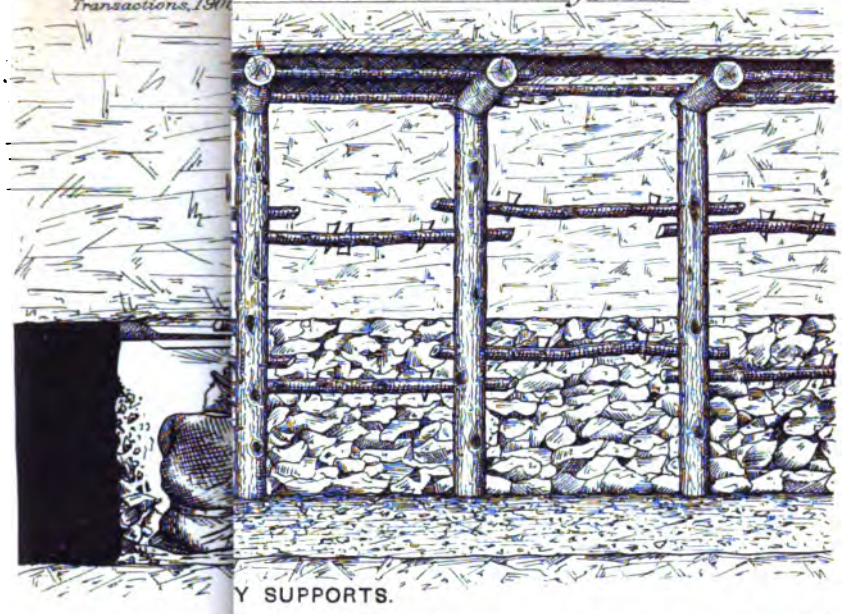
The remarkable fact set forth, is the reduction in the death-rate from falls to the extraordinarily low figures of 0·15 per 1,000 persons employed and 0·39 per 1,000,000 tons of mineral raised. These are not figures for one lucky year, but are averages for a period sufficiently long to warrant the assertion that they are not due to chance. Judged by either standard, the mortality in this country from falls of ground is five times as great.

The next point is to determine what share in the splendid improvement at Courrières belongs to each of the two separate remedies.

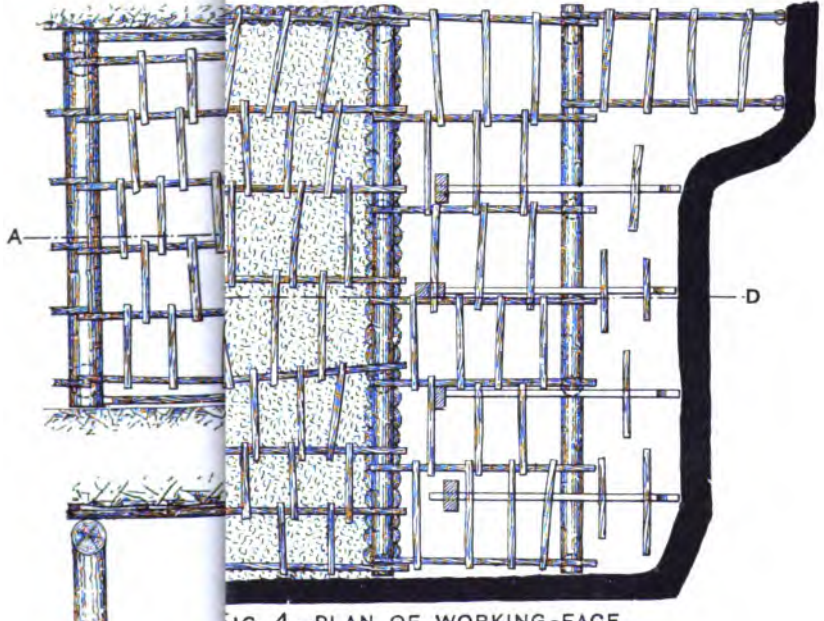
I learn from Mr. Lavaurs that systematic timbering with increased supervision was introduced in 1880, and that after trials in 1889 the use of the iron bars was made obligatory in 1890. It appears, therefore, that systematic timbering strictly enforced reduced the death-rate per 1,000 persons to one-third in the ten years 1880 to 1889, and that the employment of iron bars has now brought it down to one-fifth of what it was in the decade 1870 to 1879. The Courrières authorities consider that their present freedom from accidents by falls is largely due to this latter preventive measure.

The brilliant results at Courrières afford ample proof of the value of two of the precautions recommended in the Home Office Circular of August 9th, 1899, and warrant the prediction that the British death-rate will be very considerably lessened if these remedies are applied universally. If, further, the temporary iron supports are employed, there seems no reason why we should not in time bring down our death-rate as low as that of Courrières. This would mean a diminution in our death-roll by falls of ground from 450 to 90, or a saving of 360 lives annually, to say nothing of the prevention of many hundreds of non-fatal accidents.

Objectors may rise up and say that Courrières is a safe mine, and that it is absurd to dream of reducing our heavy death-rate



...Y SUPPORTS.



...IG. 4.—PLAN OF WORKING-FACE.

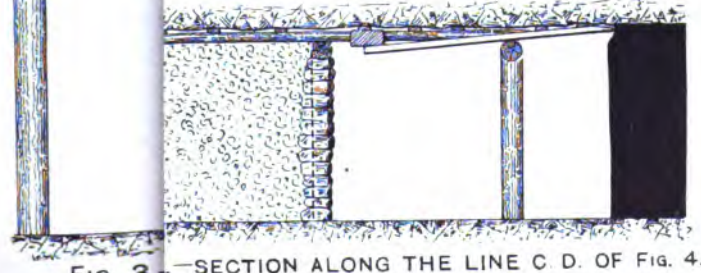


FIG. 3.—SECTION ALONG THE LINE C D. OF FIG. 4.

by falls to that of some favourable example in France. My answer would be that Tables I. and II. are quite sufficient to refute this contention. They show that twenty years ago falls of ground were just as fatal per 1,000 persons at Courrières as they are with us now, and that reckoning by the 1,000,000 tons raised there was very little difference between us. These facts completely upset the supposition that Courrières can be called specially safe from natural causes.

To say the very least, the Courrières methods deserve the earnest consideration of mining men. If my diagrams do not suffice to explain the principles to them, let them study the full-size representation at the Paris Exhibition, or, better still, visit the mine itself, which can be reached in less than 9 hours from London.

Mr. W. Logan (Langley Park) wrote that the Home Office, under date of September 27th last, had issued a circular letter, stating that: "The adoption of the methods described by Dr. Foster has resulted in so striking a reduction at Courrières of the number of accidents from falls that they deserve, in the opinion of the Secretary of State, the serious attention of coal-owners in this country."

As this letter had been sent to every coal-owner in the United Kingdom, he proposed to examine briefly whether there is anything in the method of timbering from which mining engineers can learn a lesson, or which can be applied to the coal-mines of the North of England.

An examination shows that an enormous quantity of timber is required. In a narrow heading, 6½ feet wide, and in a length of 7½ feet, there are 4 props, 8 inches in diameter; and 2 headtrees, also 8 inches in diameter. On the top of the headtrees, there are 12 rails, each 4 feet by 2 inches by 1 inch; and along the sides there are 8 rails of the same dimensions. In addition, the rails laid on the headtrees carry 35 short rails, each 1½ feet long by 2 inches by 1 inch, the whole forming a net-work of timber on the headtrees; so that 46 per cent. of the superficial area of the roof is covered with timber.

With such an apparently friable roof, and necessitating so enormous a quantity of timber, we can easily understand that it is necessary to supply each worker with three iron bars, 1⅜

inches square and 4¼ feet long, which he uses as a temporary shield in advance of the last row of timber-props, and it is apparently these iron bars which we are advised to adopt.

If he (Mr. Logan) had a roof of the character which presumably occurred at Courrières, he would adopt their system and probably improve upon it. Over a limited area, he had had to deal with an even worse roof, and he had done so, successfully, without injury to life or limb.

The Home Office seems to have got a fixed idea that systematic timbering on the principle of one prop or two props to every square foot of roof, is the universal panacea to reduce the death-rate from falls of roof and side. But now Dr. Foster tells mining engineers that if they adopt that system, with the addition of iron bars, the mortality will be reduced to one-fifth of its present rate, or from 450 to 90 per annum.

Colliery-owners and their managers are as anxious as the Home office or Dr. Foster to reduce the mortality, and they daily and for years past have adopted what is better in his (Mr. Logan's) opinion, than chequer-board systematic timbering; they have employed skilled men with brains to set timber wherever required; and there is no colliery-owner who would ask or expect his manager to reduce his working-cost at the expense of life.

Statistics for 1899 give 456 as the mortality from falls of roof and side for the United Kingdom, coal-mines being responsible for 437 and metalliferous mines for 19 deaths. There are 323 put down to falls of roof at the working-face, but it is impossible, without reading the description of every accident, to check this, so we must accept the figures.

Dr. Foster gives the average death-rate from falls per 1,000,000 tons of mineral raised during the last 10 years as: United Kingdom, 2·16; France, 2·04; and Courrières, 0·39. Consequently while we are slightly above France, as a whole, we are 5½ times above Courrières. If he (Mr. Logan) had to argue from isolated districts, or from isolated collieries, he would have no difficulty in finding collieries in the North of England where no death had occurred during the last ten years from falls of roof or side in any part of the mine.

Mr. J. L. Hedley (H.M. Inspector of Mines) remarked that all coal-mines were not alike, and a system applicable to one was not suitable to another mine. The method might or might

not be of use in the coal-mines of Durham and Northumberland; but as a matter of fact, the system was necessary in the Cumberland iron ore-mines, and had been adopted in every mine in the district for some years past.

Mr. W. C. Blackett (Durham) said that he had been surprised to receive the Home Office letter, and his first impression was one of resentment. The issue of such a letter was not complimentary to the mining engineers of this country, and he hoped that they were not reduced to learning from a single group of mines in France, how to safeguard the lives of their workers at the coal-face.

The method of timbering described by Dr. Foster was old and wellknown in this country, and spiling was often used, of wood or iron, as circumstances required. The description was bald in the extreme and no detail was given as to the number of workers and output throughout the periods covered. He could, however, gather that the output per person employed had largely increased in later years; should this also be credited to the method of timbering?

He had no doubt that, in all probability, the Home Office had approached the subject from the wrong end, and that instead of assuming that in this country they were only now in the position of things represented by the high death-rate of the Courrières mines from falls of ground in 1870-1879, they should really be compared with the state of comparative safety now reached at Courrières, and that as a matter of fact the real conclusion to be drawn is that Courrières has at last learned to timber its mines as well as they did in Great Britain.

The method of comparing individual collieries with a whole country was objectionable, as there were many large mines in this country which would, individually, show as good results as Courrières. He (Mr. Blackett) had one in his mind which showed during the last 10 years a death-rate from falls at the face of *nil*.

To effect these "brilliant results at Courrières" most importance seemed to be attached to the spiling by iron bars; but the increased supervision, introduced in the second decade, which they in this country would in all probability have considered proper to have employed in the first decade, is very lightly passed over.

Mining engineers in this country, unless they are to consider themselves slighted, should be placed in possession of the entire history of the Courrières mines, with yearly particulars and full details of the workpeople employed, etc.

Mr. G. B. Forster (Newcastle-upon-Tyne) said it would appear that from 1870 to 1879 the results at the Courrières mines were better than in this country, so that they had not commenced badly. The increased tonnage and number of persons employed, did not enter into the calculation, as all figures were reduced to ratios. It was necessary to go very carefully into the statistics, so as to throw every possible light upon the subject. It was desirable, also, that we should have a detailed account of the Courrières mines, the nature of the roof, and the system of working. He would also like to know whether the accidents occurred from falls of top or side.

Mr. W. O. Wood (South Hetton) remarked that Dr. Foster seemed to assume at once that the methods of timbering in Great Britain were inferior to the French system, and that both were inferior to the system adopted at Courrières. He thought that Dr. Foster was mistaken, and that the systems of timbering in use in Great Britain were better than those which yielded improved results at Courrières. Dr. Foster suggested that if the Courrières system were adopted the diminution of the death-roll would result in a saving of 360 lives annually, and in the prevention of many hundreds of non-fatal accidents.

In a British colliery, drawing 10,000,000 tons of coal during the 10 years ending 1898, the average death-rate per 1,000 persons employed underground was 0·04 compared with 0·15 at Courrières colliery, and the average death-rate per 1,000,000 tons was 0·10, as against 0·39 at Courrières. The system of timbering at this colliery was very efficient: the accidents, as a rule, at the face were such as could not be guarded against, and were very few in number—there had been only 1 fatal accident during the 10 years. At the same colliery, there were 12 accidents due to falls of roof and side, but not to falls at the face; 5 deaths arising from drawing timber; 2 deaths from falls of top coal, left by the workmen against orders; 1 death by going into the goaf; 1 death by knocking out a prop; 1 death from a fall of stone, while repairing a return air-course; and 2 deaths by neglecting

to erect timber to support stone in a tramway, when ordered by the master-shifter. This total of 13 deaths from all causes of falls, showed a death-rate of 1·30 per 1,000,000 tons of mineral, which compared satisfactorily with that for the whole of France (2·04).

Mr. W. C. Blackett said that 3·13 deaths per 1,000,000 tons of mineral was given as the average death-rate from "falls of ground" at Courrières. In 1880, "systematic timbering with increased supervision," was introduced and the death-rate was reduced to 0·70; whereas Dr. Foster claimed that the introduction of iron bars had effected the improvement after 1890. He (Mr. Blackett) was of opinion that the decreased mortality arose from the "increased supervision" introduced in 1880. He had particulars from one colliery for over 10 years, drawing about 250,000 tons of coal each year, and during those 10 years there had not been a fatal accident of any description to a hewer at the face. He would not dream of stating that the system of timbering in use at that colliery should be recommended for adoption in France or elsewhere. The colliery was simply as well looked after as other collieries are looked after by the deputies in this district. At another colliery, during the years 1889, 1890 and 1891, a run of misfortune occurred, and the death-rate rose to about 8 per 1,000,000 tons, but during the next 6 years there was no fatality of any kind. If during those 6 years, any alteration had been made in the method of timbering it would have been very fallacious to have attributed the immunity from accident to such a cause.

Mr. M. H. Douglas (Usworth) stated that iron bars had been in use for the past 25 or 30 years in collieries in South Wales. It was invariably necessary to drive 3 bars over the last bar in ripping a gateway or wagonway canch, before the next bar was inserted.

Mr. G. B. Forster, referring to the results following upon increased supervision, said it was true that the death-rate was much reduced in the period from 1880 to 1889, but in the following period of 10 years it was reduced by about 50 per cent.

Mr. T. E. Forster remarked that British statistics should distinguish accidents from falls of roof and side. He had noticed,

on analysing the official statistics, that workmen were being killed not so much at the face, as back-bye and in other places where the Courrières system of timbering would not have reduced the mortality. It seemed to him that the spile-system had been devised for a special mine, with a particular class of roof, which had not been described by Dr. Foster. The system of timbering was adopted in the Cumberland iron ore-mines, where it was necessary, but no one would adopt it in an ordinary Northumberland colliery.

Prof. HENRY LOUIS endorsed the necessity for more information, and a separation of deaths from falls at the face from those due to falls of ground elsewhere. Dr. Foster's observations were based on official statistics, they were not suggestions or hypotheses, and if we are to accept official statistics, we could not help accepting his figures. These figures showed that the Courrières mine, 20 years ago, was less dangerous than the mines of the United Kingdom, and they also showed that from the first to the second decade the death-rate had diminished by two-thirds. Dr. Le Neve Foster, however, stated that "systematic timbering with increased supervision was introduced in 1880," consequently this question of systematic timbering was a very particular point, and he thought that Dr. Le Neve Foster desired to draw attention to the decrease in the death-rate as due no less to systematic timbering than to the use of iron bars.

Mr. C. C. LEACH (Seghill), referring to the different conditions which existed at various collieries, remarked that very considerable differences occurred in different parts of the same pit. He understood that timber was not drawn at the French collieries.

The PRESIDENT (Mr. J. G. Weeks) enquired whether "falls of ground" included all falls of roof and side, or whether the term was limited to the working-face; and whether it included falls of coal. The supporting of the roof with iron bars would not prevent falls of coal. If the timber supporting the roof was not taken out the risk of accident to those drawing the timber would be lessened, but it would add very considerably to the expense of working.

Mr. J. L. HEDLEY said that in his reports "falls of side" included falls of coal, but in metalliferous mines, "falls of

ground" included all sources of accident. It would be difficult to make a comparison of British and French statistics, unless the classification was the same in both countries.

Mr. SIDNEY BATES (Mickley) wrote that Dr. Foster gave every credit to the systematic timbering in use at the Courrières collieries. The results are satisfactory, but not of such importance as to require British mining engineers to adopt the Courrières method. Before a true comparison can be made of the results of the Courrières system and those obtained in some of the Northumberland collieries, the heights of the seams and breadths of working-places should be taken into consideration, together with the output per person employed underground. At a Northumberland colliery, the heights of the seams varied from 22 inches to 4 feet, the breadths of the working-places from 6 feet to 31 feet, and during a period of 20 years ending December, 1899, with an average daily output during the 20 years of about 1,200 tons, the following results were obtained, namely:—Average death-rate per 1,000,000 tons of mineral raised, 0·17; per 1,000 persons employed underground, 0·07; and the output per person employed underground was 1·64 tons. At Courrières, the seams vary in height from 2 feet 8 inches to 3 feet 7 inches; the breadth of the working-places from 6½ feet to 10 feet; the output per person employed underground was 1·09 tons; the average death-rate per 1,000,000 tons of mineral raised, 0·39; and per 1,000 persons employed underground, 0·15. The preceding comparison does not support the exceptional advantages claimed for the use of bars, although the roof in all the working-places is sufficiently tender to demand careful supervision and systematic timbering.

Mr. M. WALTON BROWN (Newcastle-upon-Tyne) said that he had prepared Table III. from the figures contained in Dr. C. Le Neve Foster's description of the cantilever method of timbering at the Courrières collieries. The tonnage of mineral raised had been obtained from the annual reports of the coal company as published in the *Revue de Législation des Mines*; the average number of persons employed underground per annum is obtained on dividing D by F, multiplied by 1,000, and the errors should not exceed 1 per cent.; the average annual output of mineral per person employed underground is the mean result of dividing F by E, and A by B, multiplied in each case by 1,000, and

the errors should not exceed 1½ per cent.; the number of deaths from falls of ground are the products of A by E, divided by 1,000,000, and the figures should be correct; and G, H and I, have been extracted from information issued by the Courrières Company.

TABLE III.—Courrières Collieries.

Decennial Periods.		1870-1879.	1880-1889.	1890-1899.	Totals and Averages.
A. Mineral raised	Tons	3,837,191	8,537,928	15,237,838	27,612,957
B. Average Number of Persons employed Underground per Annum ...	No.	1,580	2,500	4,000	2,690
C. Average Annual Output of Mineral per Person employed Underground	Tons	240	340	380	340
D. Deaths from Falls of Ground	No.	12	6	6	24
E. Average Death-rate from Falls of Ground per 1,000,000 Tons of Mineral raised ...	No.	3·13	0·70	0·39	0·87
F. Average Death-rate from Falls of Ground per 1,000 Persons employed Underground...	No.	0·76	0·24	0·15	0·29
G. Deaths Underground from all Causes ...	No.	20	11	18	49
H. Average Death-rate, Underground, from all Causes, per 1,000,000 Tons of Mineral raised ...	No.	5·21	1·29	1·18	1·77
I. Average Death-rate, Underground, from all Causes, per 1,000 Persons employed Underground	No.	1·27	0·44	0·44	0·60

An official classification of accidents from falls of ground in Great Britain, according to the place of occurrence, is shewn in Table IV.* and of the 323 deaths from falls of ground at the coal-face, Dr. Foster states that "360 (*sic*) lives annually" will be saved by the use of the "temporary iron supports."†

The first pit of the Courrières collieries was sunk in 1849, and coal-drawing commenced in 1851; 2 pits were working in 1857; 3 pits in 1862; 4 pits in 1868; 5 pits in 1878; 6 pits in 1879; 7 pits in 1892; and 8 pits since 1897. In 1899, upwards of 6,000 tons of coal was drawn per day and 1,930,868

* *Mines and Quarries: General Report and Statistics for 1899*, page 73.

† *Trans. Inst. M.E.*, vol. xx., page 166.

tons per annum, 5,794 persons being employed underground. It is stated that gas has not been found in any of the mines, that naked lights are exclusively employed (Fig. 1, Plate V.), and there has never been an explosion. The goafs are all tightly packed, but spontaneous fires occasionally occur in certain seams.

TABLE IV.—ACCIDENTS FROM FALLS OF GROUND IN MINES IN GREAT BRITAIN AND IRELAND IN 1899.

Places where Falls of Ground occurred.	Number of Fatal Accidents.	Number of Deaths.	Death-rate per 1,000 Persons employed Underground.
Working-face	318	323	0·535
Roads: Repairing or enlargin ...	75	79	0·131
Do Working or passing ...	50	54	0·089
Totals	443	456	0·755

Recently, Mr. Lucien Fèvre (inspector of mines in charge of the district) and Mr. Cuvelette (inspector of mines) had written, respecting the cantilever system of timbering, as follows:—

Mr. August Bar, manager of the Courrières collieries, has adopted since 1890 the use of iron bars for the temporary support of the working-places. These bars, made of square iron, 1¼ inches (0·035 metre) square, and about 4 feet (1·20 metres) long, provide a solid provisional protection until the erection of the final timbering. At the Lens collieries, these bars are used of I section, which renders them more handy and gives them much greater strength. It is possible that an important diminution in the number of accidents produced by falls of blocks in the working-places may be attributed to their use.*

DISCUSSION OF MR. M. WALTON BROWN'S PAPER ON "MECHANICAL VENTILATORS."†

The PRESIDENT (Mr. J. G. Weeks) said that at a general meeting of The Institution of Mining Engineers a vote of thanks had been passed to the Committee for their labours in regard to this report; but he, in common with many members of the North of England Institute of Mining and Mechanical Engineers was not able to be present at that meeting, and he

* *Notice Géologique et Historique sur les Bassins du Pas-de-Calais et du Boulonnais.* By Messrs. Fèvre et Cuvelette, Ingénieurs au Corps des Mines, page 142.

† *Trans. Inst. M.E.*, vol. xvii., page 482; vol. xviii., page 488; and vol. xix., page 398.

would like to take this opportunity of expressing the thanks of the members to the Committee for their arduous and lengthy labours, and to Mr. M. Walton Brown for the trouble that he had taken in compiling the valuable *Report*.

Mr. G. B. FORSTER seconded the vote of thanks, which was cordially approved.

Mr. H. W. G. HALBAUM (Gateshead) said that he recognized the supreme difficulty of the work of the Committee, and he thought that no man appreciated the great intrinsic value of the *Report* more than he did. It was quite clear to any person who had really studied this question that it was impossible to obtain absolutely accurate results from the purely numerical standpoint, but with the general conclusions of the Committee, approximate as they must of necessity be, he was in full agreement. One of these conclusions related to the marked superiority of the Guibal type of ventilator. Some engineers seemed to think that the claims of the Guibal fan had been rather too willingly, if not also too hastily, conceded by the Committee; but in his opinion, if there was indeed any fan that received less than fairplay at the hands of the Committee, or if there was any fan of the series which did not have a perfect opportunity of demonstrating its real capabilities, that was the Guibal fan. Taking one example only—a case in which the actual work of the machine showed the least disagreement with the Committee's estimate of its powers—it would be seen that, with respect to the Guibal fan at Cwmaman colliery (Tables 2 and 25)* the column of "differences" compared very favourably with the corresponding columns in the tables of work done by the other eleven ventilating-machines.

But, notwithstanding this fact, it would seem that the Committee were a long way out in their estimate of this machine, and that they largely underrated its real capabilities. Considered as positive numerical values, the differences shown in the last column of Table 25 were, no doubt, very small; but the real significance of a figure could not be judged by its positive value alone. The object of the tests conducted by the Committee was to ascertain the power of the fan to produce pressure, and to get at the proportion or amount of pressure expended in overcoming

* *Trans. Inst. M.E.*, vol. xvii., pages 523 and 571.

the resistance of the fan itself to the passage of volume. And if those small positive values in the column of differences were stated as percentage errors in the estimate of the fan's resistance, or as percentage errors in the estimate of the volume, the real significance of the differences would be evident. The "straight-line equation" for this fan, as determined by the Committee, was given at the foot of Table 25. At the normal velocity of 100 feet per second, the fan was estimated to give an initial pressure, H, of 2·606 inches of water-column; and the numerical measure of the fan's resistance, h_o, to the passage of the volume, V, was estimated to be equal to 0·000,000,000,045 of the square of the volume traversing the fan. Thus, on these assumptions, the effective pressure, h, available for ventilating the mine proper, was deduced to be, at normal velocity and density,

$$h = 2{\cdot}606 - 0{\cdot}000{,}000{,}000{,}045\mathrm{V}^2 \quad . \quad . \quad . \quad . \quad (1)$$

It could, however, be easily shown that the equation was not even approximately true; for example, by transposition,

$$\frac{45\mathrm{V}^2}{10^{12}\,(2{\cdot}606 - h)} = 1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

But, if they substituted in this equation the numerical values of V and h observed in the four experiments of Table 25, they found that the resulting quotient was always much greater or else much less than unity. The quotients range in value from $-0{\cdot}7$ to $+1{\cdot}97$, representing errors in the estimate of 32 to 170 per cent. These four experiments were made on artificial equivalent orifices ranging from 4 to 10 square feet. But *c* experiment, Table 2, was made on the ordinary mine; and in this case, by putting in the values of V and h obtained in the experiment, the quotient of the fraction just named came out at 5·75 instead of unity: the error in the estimate thus being 475 per cent.

But the straight-line equation (1) arrived at for the Cwmaman Guibal might also be used as a formula for the volume when h and H were given. And, practically speaking, that was the most useful form of the rule; for the depression was valuable, only in so far as it was a factor of the volume, or actual ventilation: transposed into that shape, they got for the volume of air at normal velocity:—

$$\mathrm{V} = 1{,}000{,}000\sqrt{\frac{2{\cdot}606 - h}{45}}\,; \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

which would be perfectly true if the quoted equation of the straight line were true. Estimating the volumes by this rule, and comparing them with the actual volumes obtained in the several trials, the true and essentially practical significance of the apparently small discrepancies came very strikingly into evidence in the table now presented.

No. of Experiment.	Estimated Volume.	Actual Volume.	Difference in favour of the Fan.	Difference against the Fan.
	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.
1	34,641	17,212	—	17,429
2	−22,884*	21,015	43,899	—
3	27,448	38,635	11,187	—
4	51,208	42,460	—	8,748
c	38,006	91,174	53,168	—
d	111,952	133,363	21,411	—
Totals of differences			129,665	26,177

The nett difference in favour of the fan being (129,665 − 26,177 =) 103,488 cubic feet.

There were six experiments, and the average excess of volume in favour of the fan was thus 17,248 cubic feet of air per minute. It would, moreover, be noted that the greatest excess in any single experiment was that obtained in *c* experiment, the only trial in which the fan acted on the ordinary mine. In that case, the excess was over 53,000 cubic feet per minute: the actual volume thus being 140 per cent. greater than the volume estimated by the equation of the straight line. It would be seen, therefore, that if the Committee did indeed underestimate the capacity of any particular fan, they certainly did not overestimate the capabilities of the Cwmaman Guibal fan.

It would be noted that these large *plus* differences of volume in favour of the fan were coincident with the apparently small *plus* differences in Table 25. And it was practically useful to observe that the *plus* differences, as a general rule, in the case of all the Guibal fans tested, were manifested whenever the fan acted on any equivalent orifice equal to an ordinary mine. It was a matter of little moment what a fan did on orifices less than that possessed by any ordinary mine known in this country, but

* In No. 2 experiment, the observed effective depression was greater than the estimated initial depression ; consequently, the estimated volume must have a minus value, as indicated.

it was a matter of the greatest practical importance to determine the sort of duty it would perform on real work-a-day mines. And all the Guibal fans in the series, when acting on such orifices, developed much better work than was deducible from the Committee's estimate of their various capabilities, as recorded in the *Report*. On the other hand, and with the solitary exception of the Schiele fan at the Great Western colliery, none of the fans other than the Guibal type gave out their *plus* differences on orifices approximating to the ordinary and average mine. For the most part, they did better on small orifices such as nobody wanted to run them on, and worse on the larger orifices which more truly represented the real mine of everyday life. From the practical point of view, therefore, it was pretty clear that it was the Guibal type of fan rather than any other machine, which received the scantiest justice at the hands of the Committee.

It was not stated in the *Report* whether all the Guibal fans in the series were handicapped in the same way as the Cwmaman machine, but the cause of the irregularities observed at Cwmaman was, in his opinion, quite evident. They were informed in the *Report* that the sliding-shutter of this fan was fixed immovably, so that the area of opening presumably remained constant throughout the experiments. One could easily understand that this amount of opening would be that which had been found most suitable for the ordinary mine; and that view would explain the fact that the Cwmaman fan gave a better efficiency in every respect when acting on the ordinary mine than it did on any of the small orifices, or even on the larger orifice created by opening the separation-doors. The sliding-shutter was really an essential detail, or an integral part, of the Guibal fan; and if the machine was to have a fair chance of developing its best work on each of a series of orifices, the proper regulation of the amount of opening at each change of the equivalent orifice was indispensable. Prof. T. Guibal, the designer of this comparatively early type of fan, recognized what hardly any modern designer of fans seemed to have grasped, namely, that the velocity generated in the air by centrifugal force, and the area on which that velocity was permitted to act, should be made exact coefficients of each other, with the actual volume of air as their product. And so long as fans were constructed on their present lines that

end could only be attained by means of the sliding-shutter. If this fundamental principle was taken into account, and if, in the light of that principle, the Committee's figures were accordingly modified, it would be found that the true orifice of passage possessed by the Cwmaman Guibal fan was much nearer 70 square feet than the 55 square feet with which it had been credited, and that its manometric efficiency was more like 65 per cent. than the 61 per cent. assigned by the Committee.

The *Report* did not inform the members whether the other Guibal fans experimented with were, in common with the Cwmaman machine, fitted with sliding-shutters incapable of sliding. But he noticed in one part of the account that Mr. M. Walton Brown, speaking of the fans generally, referred to the "so-called sliding-shutter,"—an expression that appeared sufficiently suggestive. But no Guibal fan was ever intended to work on all sizes of orifices with a sliding-shutter immovably fixed, nor was it conceivable that any engineer would agree with the proposition that a sliding-shutter must of necessity degenerate into an immovable fixture. If it was really under such conditions, however, that the four Guibal fans came out of the tests victoriously, it would have to be admitted that there was little danger of this type of fan being superseded for some time to come. It was, nevertheless, necessary to remember that a fan so handicapped ceased, for the time being, to be a true Guibal fan; and also, as Mr. Murgue himself had pointed out,* that results obtained from covered fans having a constant area of outlet really lay beyond the scope of those methods of comparison and measurement which were associated with the theory of the equivalent orifice. But, apart from that consideration, it seemed practically certain that, had the Guibal type of fan obtained complete fairplay in the tests conducted by the Committee, its distinct superiority would have been demonstrated even more markedly than the *Report* already claimed it to have been.

Mr. M. Walton Brown stated that the experiments on the Guibal fans were not wholly satisfactory, on account of the engineers being unable to vary the position of the sliding-shutter.

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* *Theories and Practice of Centrifugal Ventilating Machines.* By Mr. D. Murgue, translated by Mr. A. L. Steavenson, page 31.

DISCUSSION OF MR. CLARENCE R. CLAGHORN'S "DESCRIPTION OF PRESENT AND PROPOSED METHODS OF OPERATING VINTON No. 3 COLLIERY, VINTONDALE, PENNSYLVANIA, U.S.A."*

Mr. Clarence R. Claghorn wrote that he was glad to be able to report that his experimental longwall working had now got beyond the experimental stage, and had proved very successful. The efficiency of their men had been more than doubled and the "hewing-and-filling" cost reduced 50 per cent. They had no trouble in maintaining the roof to admit of the track along the face, and the roof worked down into the goaf after every second holing.

DISCUSSION OF MR. W. RIPPER'S PAPER ON "A POWER-INDICATOR FOR STEAM-ENGINES.†

Mr. Philip Kirkup (Birtley) remarked that the instrument designed by Mr. Ripper could not be looked upon as superseding indicator-diagrams for the following reasons: —(1) The instrument only determined the horsepower of the engine, and gave no indication of the amount of steam used to perform this work; and (2) indicator-cards are usually taken to show the distribution of the steam in the cylinder, whether the valves are set right and to determine if there be any piston-leakage, none of which points are shown with Mr. Ripper's instrument. It seemed to him (Mr. Kirkup) that this instrument would give misleading results in at least two cases, namely: (1) If expansion occurred so early in the stroke as to allow the steam-line to fall below the back-pressure line; and (2) if cushioning occurred so early in the stroke as to compress the steam in the cylinder above its initial pressure. In both of these cases, Mr. Ripper's instrument would indicate greater power than was actually present; and either of these cases may occur, if the slide-valve shifted on its spindle. Mr. W. H. Chambers was not quite correct in stating that the instrument would facilitate the registering of the duty of engines. The ordinary indicator will not register the duty but only the pressure, and with the Ripper indicator there is no means of ascertaining the duty.

* *Trans. Inst. M.E.*, 1900, vol. xviii., page 351.

† *Ibid.*, vol. xviii., page 402.

Mr. C. C. LEACH (Seghill) said that no indicator would show the amount of steam used in the cylinders, and the indicator-card did not by any means show the whole consumption. The correct method was to measure the amount of water boiled away, as no indicator would show the weight of steam used by an engine.

Mr. PHILIP KIRKUP said that he did not consider the steam evaporated by the boiler as equivalent to the steam consumed by an engine.

Mr. W. RIPPER, replying to the discussion, wrote that he agreed with Mr. Kirkup that the readings by his instrument do not supersede indicator-diagrams, except where the horse-power of the engine only is required, and then the readings by the instrument save the trouble of taking indicator-diagrams. It does, further, give a continuous indication of the power exerted by the engine. It is, however, a mistake to suppose that an indicator of the ordinary kind will show the amount of steam used by an engine in the performance of its work, or to suppose that it will show whether there is piston-leakage or not.

DISCUSSION OF MR. WM. TAYLOR HESLOP'S PAPER ON "THE COAL-FIELDS OF NATAL."*

Mr. C. WILSON-MOORE (Transvaal) wrote that the members had received a valuable contribution in the shape of Mr. Heslop's paper on the coal-fields of Natal.

He did not think that much, if any, doubt remained as to the geological horizon of the South African Coal-measures. The Lower Karoo Beds with the Dwyka Conglomerate at their base are unquestionably of Triassic age, and in no case has coal been found below the Dwyka Conglomerate.

If he understood Mr. Dunn's hypothesis correctly, as set forth in Mr. Heslop's paper, the late Government Geologist of the Cape Colony based his theory as to there being a second or lower series of Coal-measures below the Stormberg Beds of the Cape Colony, upon the fact that the Vereeniging Coal-measures lie immediately upon the Dwyka Conglomerate. But the Beaufort and Ecca Beds are entirely absent there, and in all probability

* *Trans. Inst. M. F.*, 1900, vol. xviii., page 410.

have always been so. If geological sections could be correlated across the areas occupied by the Vereeniging Coal-measures, the Beaufort and Ecca Beds of Natal with those of the Stormberg, and by means of remnant outliers show that these beds once occupied an horizon *in situ* above the Vereeniging coal-seams, Mr. Dunn's theory might be accepted as correct. He did not think that this could be proved, and, seeing that the Beaufort and Ecca Beds and the Dwyka Conglomerate are, in sequence, correctly underlying the Natal Coal-measures, there does not appear to be any reason to doubt that the age of the Cape Colony, Orange River Colony, Transvaal and Natal Coal-measures is the same. Merely because the Vereeniging coal-seams lie directly upon the Dwyka Conglomerate, we must not assume a second horizon. If such a theory were to be followed to its direct logical conclusion, we should have to establish a still lower coal-horizon in South Africa; for in the eastern portion of the Transvaal, under the Lebombo Mountains, occur areas of coal lying directly upon granitoid rocks, which latter underlie the Berg Sandstones and Conglomerates, these in turn being the lowest group in Dr. Molengraaff's Table Mountain Series. These isolated areas under the Lebombo Mountains are known to be downthrows from the main Transvaal and Natal Coal-measures, although often 150 and even more miles away from the nearest coal-fields.

He was afraid that the dream of a large coal-field in the Cape Colony beneath the Karoo Beds was nothing more than a dream. In the Cape blue book,* Mr. Dunn, in a short description of the geology of the Indwe district, gave the thickness of the Karoo Beds at 5,000 feet; that is, he (Mr. Wilson-Moore) presumed, the thickness of the Lower Karoo Beds below the Molteno Beds or Coal-measures horizon there, and include, according to Dr. Molengraaff, the Beaufort and Ecca Beds.

Railway management in South Africa is on the verge, it is hoped, of great improvement, so far as inter-colonial traffic and rates are concerned. So that under any circumstances it does not appear probable that the boring through several thousands of feet for a problematical coal-field lying on the hidden Dwyka Conglomerate is likely to be undertaken, while immense areas of easily available coal are in existence and the fields themselves are everywhere tapped by main trunk railway-lines.

* G. 35, 1883, page 8.

Finally, if there be coal under the Beaufort and Ecca Beds in Cape Colony, why are there no traces of its existence at the outcrop of the Dwyka Conglomerate in the south of Cape Colony? Or, perhaps, one would ask whether there are any such traces?

As Mr. Heslop said, the palæontological evidence as to the age of the Coal-measures in South Africa was very unsatisfactory and confusing; but with the experience gained among the Australian and Indian Coal-measures, added to the practical certainty as regarded the stratigraphy of the Coal-measures here, it seemed most probable that the Carboniferous fossils found in the South African Coal-measures were survivals into Triassic times.

Some years ago, when Curator of the Chamber of Mines' Mineral Museum in Johannesburg, he (Mr. Wilson-Moore) heard of a fossil fish having been found at Boksburg. He went out post-haste to secure it, and on arrival asked for the collier who had found it. He acknowledged the discovery, and stated that he had "stuck 'im up on end, and shied stones at him!" The remnants could not be found, and so a possible clue to the age of the Transvaal Coal-measures was lost for ever. This want of fossil evidence is very marked throughout the majority of South African strata, and is not peculiar to the Coal-measures.

The dolerite-dykes and sheets, mentioned by Mr. Heslop, are, petrologically, practically identical with the dolerite which occurs so generally, and over such enormous areas throughout South Africa. It may be said to be South Africa's typical vulcanic rock. He agreed with Mr. Heslop that the sheets were intrusive and not merely surface or submarine deposits. He had had occasion to examine many of these sheets, and had invariably been able to trace them to their parent dyke or dykes. The rock itself was not, however, always a purely typical dolerite, that is to say, it was not invariably made up of the pure labradorite, augite and olivine of the family of quartzless plagioclase-rocks. It merged at times into the minutely crystalline paste of quartz, plagioclase, augite and olivine, known as quartz-dolerite, and contained at times, as was found on the Rand, crystals of calcite, occasionally measuring an inch cube. Such a variety occurred above and about the coal-areas at Springs, Boksburg, and the Cassel Company's coal-mine near by. Occasionally, magnetite was found in the intrusive rock, which would bring it very near

a basalt. Mr. Dunn mentioned that the dolerite above the Cave Sandstones was "rudely columnar," which also conveyed the impression that a basalt had been reached. Could Mr. Heslop state whether he had noticed this columnar structure in the Natal coal-fields? Or did the dolerite show its spheroidal structure by weathering in nodules, as was so common in South Africa? Mr. Dunn agreed with Mr. Heslop in his observations as to the effect on the coal of the intrusions of dolerite; and identical results obtain in the Indwe coal-field.

Not the least valuable portion of Mr. Heslop's very able paper was the remark that "roughly speaking, the coal is found unaffected at a distance from the dyke, equal to the thickness of the dyke," and the figures given in support thereof. If this rule could be generally substantiated throughout South Africa, it would aid engineers every considerably in the laying out of their works. It was to be hoped that Mr. Heslop would be at liberty to continue these very important observations; and if so, he could suggest that they might be extended by observations as to the extent to which the roofs and floors of the coal-seams are affected by intrusive sheets above and below, and at what thickness and character of intervening strata—upon this point Mr. Heslop is silent. Finally, could any British mining engineer give any particulars of observations as to the effects on coal from similar intrusive dykes, and if so, did Mr. Heslop's rough rule apply?

Mr. T. Rasmussen's description of a "Shot-hole Recesser" was read as follows:—

SHOT-HOLE RECESSER.

By T. RASMUSSEN.

This machine is intended to form a recess, for the reception of the explosive, in shot-holes, in an easy and expeditious manner.

By inserting the tool, and turning and feeding the cutters outward, a recess is formed of any required length, the diameter of the recess being determined by the outward travel of the cutters.

After the hole is recessed, as required, the feed-wheel or handle is unscrewed, and the cutters are pushed back into the head, after which the machine is easily withdrawn.

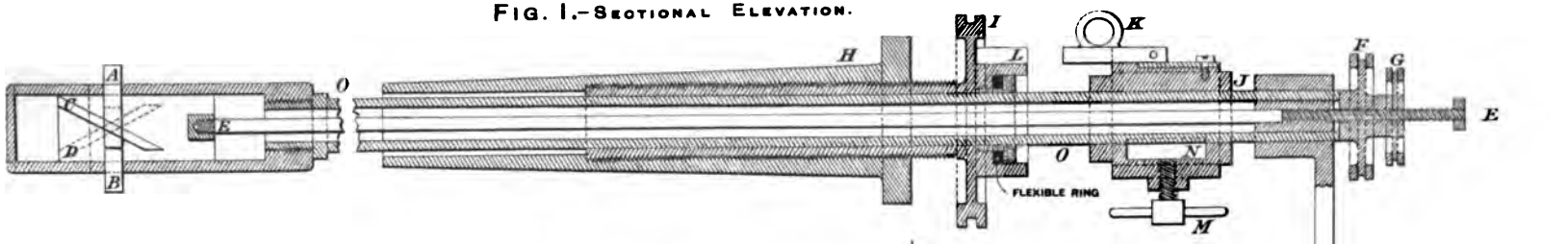
The tool is shewn in Figs. 1 and 2 (Plate VI.) with some of the parts slightly separated. By turning the feed-wheel, *F*, the rod, *E*, and the block fitted with the external projection, *C* and *D*, are drawn outward, and the cutters, *A* and *B*, are projected laterally from the tool.

After the shot-hole is made in the usual way, it is cleaned out, and the machine is inserted and pushed to the back-end of the hole. The feed-bush, *I*, being screwed into the tapered-bush, *H*, the latter is placed firmly into the mouth of the hole. The thrust-bush is slid down to its position, against the feed-bush, *I*, the clutch or key, *K*, being thrown out, and it is fixed upon the tube, *O*, by the set-screw, *M*. The handle, which is fixed to the tube, is turned to the right, like a clock; the feed-wheel, *F*, is turned to the left; and the cutters, *A* and *B*, travel outward to their full extent, and the check-wheel, *G*, is turned so as to lock the feed-wheel, *F*. The clutch, *K*, is then placed into the slot, *L*. The handle is then turned to the right, carrying with it the feed-wheel, *F*, until the recess for the explosive is made of the desired length. The machine is removed from the hole, by slacking the wheels, *G* and *F*; the rod, *E*, is then pressed back by a light tap; and the cutters are simultaneously withdrawn into the machine.

The Institution of Mining Engineers
Transactions, 1900-1901.

To illustrate Mr. T. Rasmussen's Description of a "Shot-hole Recesser."

FIG. 1.—SECTIONAL ELEVATION.



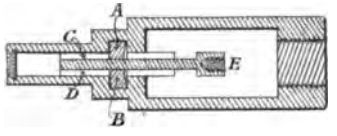


FIG. 2.—SECTIONAL PLAN.

FIG. 3.—CROSS SECTION AT LINE A B, FIGS. 1 & 2.

FIG. 4.—CROSS SECTION AT LINE A B, FIGS. 1 & 2.

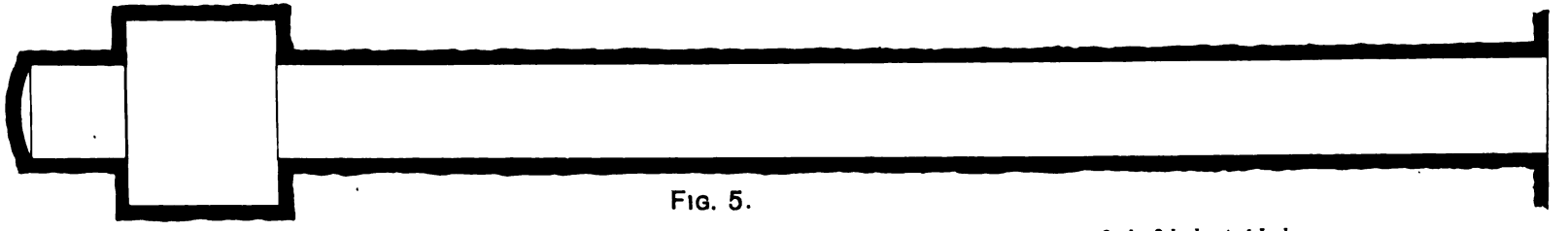


FIG. 5.

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Transactions, 1900-1901.

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Scale, 3 Inches to 1 Inch.

The borings are left in the hole, until the machine is withdrawn, and they can be removed by a small scoop fixed on the end of a wooden rod.

This machine has an automatic feed, when boring in either coal or stone, but the wheel, *I*, can be fed by hand, if the clutch, *K*, be thrown out of gear. Hand-feeding may become necessary, if hard panels or pebbles are encountered by the cutters, while enlarging the hole.

Hardened steel cutters (Fig. 3) can be used for cutting coal and soft material; and for cutting in stone, granite or other hard material, diamonds (Fig. 4), inserted in the ends of the steel-cutters, can be used.

This machine can be inserted into a 1½ inches bore-hole, and form a recess 3 inches in diameter; or into a 2 inches bore-hole, and form a recess 4½ inches in diameter (Fig. 5).

The advantages accompanying the use of this machine include the following:—(1) The explosive is concentrated, and thus rendered more efficient; (2) there is less danger of blown-out shots; (3) it is not necessary to bore shot-holes at angles to the axis of the working-place; (4) more ground is broken with a given weight of explosives by this machine, than is accomplished by the present method of straight or smooth holes; and (5) a smaller number of holes is required, in order to remove the same weight of ground.

A ROCK-DRILL FOR SAVING SLATE-ROCK.

By H. HUMPHRIS.

For some time the writer has given this matter his attention, as the present manner of blasting slate-rock makes a larger percentage of waste than there should be: there being about 10 tons of waste rock produced before 1 ton of slates is ready for the market, hence the writer's reason for introducing his improved drill to avoid some of this waste.

In the first place, a circular hole is drilled, $1\frac{1}{8}$ inches in diameter, then his improved drill follows, Figs. 1, 2 and 3 (Plate VII.), making the hole of a double <> shape, as shown by the piece of slate-rock exhibited to the members (Fig. 4).

With this drill, not only slate-rock is saved, but less powder is used, owing to the two weak points made in the rock by the drill, *A* and *B*, as the line of splitting passes through the two weak points (Fig. 4). The same effect is produced by the improved drill in any stone, splitting it in the required directions. The writer feels assured that the improved drill could be usefully employed for this purpose in any kind of rock or stone.

The Institution of Mining Engineers
Transactions 1900-1901

To illustrate M.r H. Humphris' Description of "A Rock-drill for saving Slate-rock."

Fig. 1.—Side Elevation.

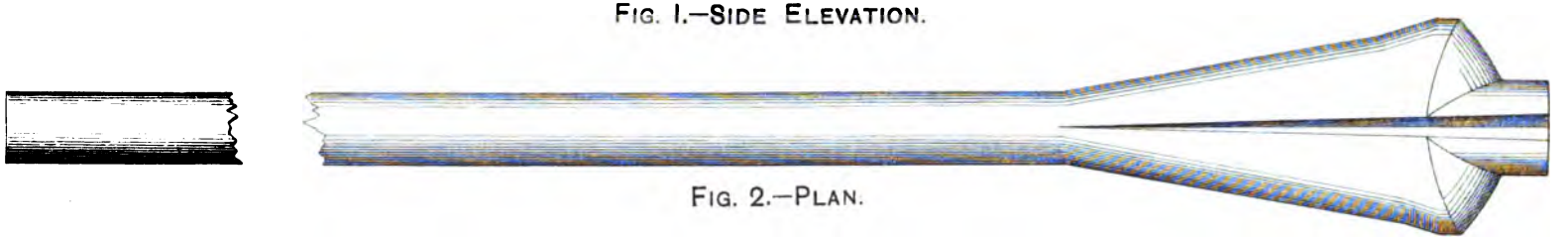

Fig. 2.—Plan.

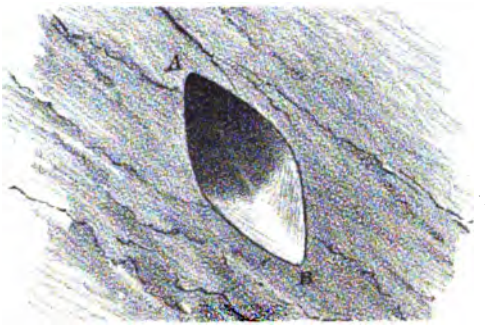

Fig. 4.

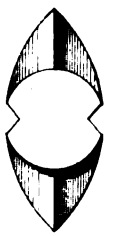

Fig. 3.—End Elevation.

Scale, 2 Inches to 1 Inch.

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THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING OF STUDENTS,
SUNDERLAND, OCTOBER 17TH, 1900.

About 50 students and associates visited the Hylton colliery, and the River Wear Commissioners' works.

HYLTON COLLIERY.

Hylton colliery is situated on the northern bank of the river Wear, about 2 miles above Sunderland. There are two coal-drawing shafts, each 20 feet in diameter, while a third shaft, 15 feet in diameter, has been sunk to the Hutton coal-seam, and will eventually be used as an independent upcast shaft.

Sinking operations were commenced in August, 1897. By the end of December in the following year, the Maudlin coal-seam had been passed through at a depth of 1,440 feet, and, later, the Hutton seam was reached at a depth of 1,580 feet from the surface. In the early months of 1900, the sinking and walling of the three shafts was completed, so far as was necessary for the winning of the Maudlin and Hutton seams. The sinking was throughout singularly devoid of incident, and at no time did the water making in any one shaft exceed 70 gallons per minute.

At the present time, only one of the permanent winding-engines has been erected: this engine has two horizontal cylinders, 34 inches in diameter by 6 feet stroke; it is fitted with Cornish or double-beat valves, and automatic expansion-gear, actuated by a pendulum-governor, worked by bevil-gearing driven from the crank-shaft. The winding-drum is 20 feet in diameter on the cleading (which is 7 inches thick, resting on a complete cylinder of steel plates), and 12 feet wide between the cheeks. There are two strap-brakes regulated by a foot-lever, and in addition there is a powerful steam-brake, having a cylinder, 8 inches in diameter. An exact counterpart of this winding-engine will shortly be erected at the second coal-drawing shaft.

Steam will be supplied to each winding-engine, from a separate battery of Lancashire boilers, 8½ feet in diameter by 30 feet long, and working at a pressure of 120 pounds per square inch. The battery at the west pit is already set, and is protected by a substantial house, the walls being built throughout of brick, with an iron roof, slated and provided with glass skylights. It is expected that two of these boilers, under steam at a time, will be amply sufficient for each winding-engine.

The two pits are connected by the heapstead, but it is intended to erect a dividing partition and to keep the coals from each seam entirely separate, each cleaning-plant having independent belts and screens. To secure efficient banking-out arrangements, the floor of the heapstead has been given a gradual slope from the pit, and the tubs, on leaving the cage, will run automatically to the weighing-machines, through the tipplers, and be carried by gravity to the back of the pit, where they will be raised by a short creeper, which will deliver them on to a kip, whence they will gravitate back to the banksmen at the pit-top. This arrangement is already at work at the west pit, and will in course of time be duplicated at the east pit. The automatic tipplers deliver the coal on to jigging-screens or picking-belts as required.

The heapstead is built of brickwork, and the screens and belts are carried on cast-iron columns and steel girders. The headgear and pulley-frames, built of steel lattice-work girders, are erected upon solid brickwork pillars, built up to the level of the floor of the heapstead. The winding-pulleys, 20 feet in diameter, on the trod, are built in segments with flat steel spokes.

The temporary cages, now in use, will be replaced by double-decked cages, carrying four 10 cwts. tubs on each deck; they will run in wire-rope guides, and the decks will be loaded and emptied at separate levels without moving the cage. The winding-ropes are 5 inches in circumference, of mild steel, and are counterbalanced by a continuous rope running beneath the cages.

Ventilation is at present produced by a small furnace placed in one of the 20 feet shafts at the level of the Five-quarter seam; and although the temperature of the air in this shaft is raised to a mean of only 66° Fahr., there is a current of 70,000 cubic feet per minute passing through the workings, which are now ½ mile from the shaft. This arrangement, of course, is only temporary, and will be replaced by a fan.

None of the haulage-plant is as yet established, but it is proposed to haul the tubs on the endless-rope system, the rope to be attached on the underside of the tub. The hauling-engine will be placed at bank, under the heapstead, in front of the winding-engine, and the ropes will be carried down the pit through collarings built into the shaft-walling. The landings will be fed by an auxiliary system of small hauling-engines placed in the workings, and drawing direct from the putting flats. These engines will be worked by compressed air, supplied at a pressure of 75 pounds per square inch. The air-compressing plant, not yet erected, will consist of a compound steam-engine, and compound air-compressors.

The colliery-site has a frontage to the North Eastern railway of 3,450 feet, and between the sidings and this branch sufficient area has been reserved for a large coking-plant.

The river-frontage is 1,050 feet long, and on it will be erected staiths for loading small vessels and river-craft, but the bulk of the output will be sent for shipment to the Sunderland docks, where there is ample accommodation for the large steamers now usual in the trade.

RIVER WEAR COMMISSIONERS' WORKS.

Sunderland Harbour Piers.

The harbour piers are now in course of construction, and were designed for increasing the depth of water in the channel and for the protection of vessels entering the port in stormy weather.

Roker pier on the north side of the Wear will, when completed, be of a total length of 2,790 feet ; of this length 2,660 feet is now finished, leaving 34 feet of pier to be constructed up to the roundhead. For 2,340 feet, the width at the top is 35 feet, and for the remaining distance, 41 feet. The width at the bottom varies with the depth and is at present 120 feet at a depth of 40 feet at low water. The top of the pier is 10 feet above high water. A subway, 6¼ feet high by 4 feet wide, runs the entire length of the pier, and will afford access to the lighthouse in stormy weather. The shore portion of this pier for a length of 385 feet was constructed of concrete *en masse*, faced with granite blocks; for the remainder of the pier the superstructure is formed of granite-faced concrete blocks, varying in weight from 43 to 54 tons, set in lengths of 42 feet 7 inches each, by a radial hydraulic block-setting crane, which can set a 60 tons block 60 feet in advance of its leading wheel. The interior of each length is filled with concrete blocks and concrete *en masse*. The superstructure is set on a foundation levelled to 2½ feet above low water. This foundation is formed of 56 and 116 tons bags of 4 to 1 concrete, deposited in a plastic condition on the rock. The concrete is enclosed in bags of jute-sacking weighing 27 ounces per yard, 30 inches wide. These bags are made in boxes, slung in the well of a Wake twin-screw bag-barge and suspended from hydraulic cylinders. The barge steams alongside a concrete mixing-house, where the bag is filled with plastic concrete and laced, the barge then proceeds to sea and is moored directly over the place where the bag is required, the box and bag are then lowered as near the bottom as possible and the bag deposited. For a length of 460 feet at the outer end of the pier, the rock is covered with a layer of sand varying in thickness from 1 to 17 feet and this is removed by a sand-pump dredger before the bags are deposited.

The roundhead will be formed, in the first place, of an iron caisson, 100½ feet long, 69 feet wide and 26½ feet deep, set on a

specially prepared foundation of concrete bags levelled to 24 feet below low water. This caisson will be floated out with a draught of 22 feet containing 3,500 tons of concrete, and will be sunk on its site by partly filling it with water. It will then be filled with 15 and 25 tons concrete blocks and cement-grouted granite rubble, and will weigh 10,000 tons; on the top of this a roundhead formed of blocks will be built, surmounted by a lighthouse containing a third order dioptric light, having a focal plane 83½ feet above high water. The total weight of the roundhead, when completed, will be 23,000 tons.

The New South pier, on the south side of the harbour, is constructed in a similar manner to the Roker pier, but varies somewhat in details. The length of the pier is 2,844 feet, of which 1,950 feet is now completed; the width of this portion is 35 feet, and that of the remainder will be 41 feet. The top of the pier is 9 feet above high water, and has a parapet-wall, 9 feet high by 9 feet wide, running along its entire length; the width of the parapet-wall will be increased to 14 feet for the remaining part of the pier. The weight of the blocks used on this pier is 15 tons, they are set on a bag-work foundation by a 20 tons block-setting crane worked by a gas-engine. The crane revolves completely, and can set a 20 tons block 64 feet in advance of its leading wheel. The foundation is constructed in the same manner as at Roker pier.

The whole of the Harbour Works are being carried out by the River Wear Commissioners' workmen, under the direction of their engineer, Mr. Henry H. Wake, M. Inst., C.E., and the engineering staff.

No. 1. Graving-dock Pumping-station.

The pumping plant at the No. 1 graving-dock consists of two 83 brake-horsepower (working), 98 brake-horsepower (maximum) Tangye gas-engines, coupled directly to two Tangye centrifugal pumps, 21 inches in diameter; and a 15 brake-horsepower Tangye gas-engine, which drives a centrifugal pump, 8 inches in diameter for pumping the dock-leakage. The large pump-discs are 5½ feet in diameter. In place of foot-valves, these pumps have flap-valves on the delivery-side of the pump. They are primed by an air-pump driven by the small gas-engine. The large engines are started by exploding a mixture of compressed gas and air, supplied from a receiver which is charged by means of a com-

pressor, connected when required to the small gas-engine by a clutch.

At a trial made in 1895, the two large pumps discharged 10,238 tons of water in 1 hour 58 minutes, the consumption of gas by the engines being 6,695 cubic feet, the average number of revolutions of the engines per minute being 125.

Two men and a leading hand attend to this pumping-plant and the pumping-plant at the No. 2 graving-dock, which consists of three 120 brake-horsepower Crossley gas-engines, coupled to three Gwynne centrifugal pumps, 22 inches in diameter.

Centrifugal pumps direct-driven by means of gas-engines were first adopted at these docks, and the system has been generally extended to other graving-docks, as it has proved an economic success.

Chain-cable and Anchor-testing Works.

These works were erected in 1874, from designs by Mr. Wake, the engineer to the River Wear Commissioners, the whole of the hydraulic plant being constructed by Messrs. J. Abbott & Co., Gateshead. At present about 10,000 tons of chain-cable and anchors are tested annually.

The machinery is worked by hydraulic power direct from an accumulator at a pressure of 2,000 pounds per square inch, and consists of a 250 tons testing-machine for testing short lengths of chain to breaking-strain, a 100 tons testing-machine for applying tensile tests to chains in 15 fathom lengths to the Board of Trade standard, and a 100 tons anchor-testing machine. Sample links for the breaking test are cut out of each length of chain by an hydraulic shearing-machine, the knife of which is stepped so as to cut one side of the link at a time. By this form of knife, which was designed by Mr. Wake, an open-jawed machine capable of shearing 2½ inches cables was successfully brought into use.

These works were the first where a complete system at so high a pressure had been adopted, and it is satisfactory to note during the long period that they have been in operation that there has not been any failure or accident in the use of the pressure-mains, plant and machinery.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
NOVEMBER 17TH, 1900.

MR. T. V. SIMPSON IN THE CHAIR.

Mr. NORMAN M. THORNTON read the following description of "Endless-rope Haulage at Pelton Colliery":—

ENDLESS-ROPE HAULAGE AT PELTON COLLIERY.

BY NORMAN M. THORNTON.

The endless-rope haulage at Pelton colliery is now delivering upwards of 1,400 tons of coal, per day of 10 working hours, to the Busty pit, 620 feet deep. The whole of the roads and sidings near the shaft are secured by brick-walling and arching, 12 inches thick; but the walls of the engine-house, and the walls near the shaft are 24 inches thick (Fig. 1, Plate VIII.).

The whole of the haulage is worked by an horizontal engine, with two cylinders, 14 inches in diameter by 30 inches stroke, and geared down by cast-steel helical gearing from 5 to 1 (Fig. 2, Plate VIII.).

Steam is generated at the surface in Lancashire boilers, 8 feet in diameter and 30 feet long, set on brick-flues and fired by the waste-gases of the coke-ovens. It is conveyed down the shaft in cast-iron pipes, 5 inches in diameter. The steam-pipes are conducted through a drift driven in the Harvey seam, 40 feet above the pit-bottom, and down a small staple to the receiver, situated in a chamber adjoining the engine-room. The steam has a pressure of 45 pounds per square inch at the engine. The exhaust-steam is passed up the shaft in pipes, 6 inches in diameter, to the surface, where it is passed into a chimney

attached to the coke-ovens, and escapes into the atmosphere. The water of condensation is passed from the receiver and hauling-engine in pipes to the water-standage.

The driving-pulleys, *A*, and the helical-teethed bevil-wheels, *B*, are placed on vertical wrought-iron shafts, *C*, 7 inches in diameter, held in position by carriages supported by girders, *D*, and resting in cast-iron footsteps, *E*, bolted upon square pitchpine baulks, 15 inches by 12 inches (Fig. 2, Plate VIII.). The Grant-Ritchie driving-pulleys (Figs. 3 and 4, Plate VIII.) are 5½ feet in diameter on the trod, and bushed with brass; they run loose on the shafts, and are easily put in and out of gear by means of friction-clutches. These pulleys, made in halves, are fastened together with screwed bolts. The flanges are adjustable, a piece of hard wood being placed between them, ⅜ inch thick, and when the flanges and ropes become worn, the wood can be taken out, reduced, re-set, and the flanges drawn closer together.

In the Grant-Ritchie friction-clutch, a brake-flange, *F*, is attached to the driving-pulley, *A*, fitted with an inner split-ring. A loose collar, *G*, is placed on the driving-shaft, *C*, so that it can be slid up and down at will, but it is forced to revolve with the shaft, as it travels over two long keys. Two arms are attached to the collar, fitted at each end with a wedge, which, when the clutch is out of gear, just enters the slits in the split-ring. To throw the clutch into gear, the collar, *G*, is moved towards the driving-pulley, *A*, and in so doing the wedge is driven into the split-ring, expanding the latter, thereby making it grip the brake-flange, *F*, and in turn causing the pulley, *A*, to revolve with it.

The ropes only pass half a turn round the driving-pulleys, and travel in-bye on the top of the tubs. There are three driving-pulleys driven by the hauling-engine, working three different main haulage-roads (Fig. 2, Plate VIII.). Two pulleys are placed on the vertical shaft on the left-hand side of the engine, and the third is placed on the shaft on the right-hand side of the engine.

One engineman attends to the hauling-engine, and the friction-clutches. From the engine-room, he can see the kips holding the full tubs, and he adjusts the speed of the ropes to the requirements of the shaft. All the ropes are usually working at

one time, and each of them can be put out of gear independently of the others, without stopping the hauling-engine; but the engineman usually slows down the engine, and on his moving the handle of the required clutch-gearing, placed beside him, that particular driving-pulley and length of rope is stopped. Electric single-stroke signal-bells are arranged in the engine-room, and ring from the different in-bye junctions.

The three main wagonways run north, south and south-west from the shaft-bottom. The west cross-cut (or south-western) wagonway was made in order to ease the south wagonway, and cuts the west wagonway at about 1,000 feet from the shaft. Formerly, the west wagonway cut the south wagonway at right angles, and the coals from both roads were delivered to the shaft along the south road, until this arrangement was found to be inadequate to deal with the large quantity of coal coming from the two districts (Fig. 1, Plate VIII.).

The speed of the rope never exceeds 3 miles per hour.

The full tubs are detached from the rope at the points, *K*, on Fig. 1 (Plate VIII.). Fig. 8 (Plate IX.) shows the automatic "knock-off" or detaching arrangement employed on the west cross-cut wagonway. It consists of two pieces of angle-iron, *A*, 12 feet long and 3 inches wide, placed side by side, and $1\frac{1}{2}$ inches apart, curved upwards towards the extremities, and held in a slightly inclined position by strong wooden hangers, *B*, while the diagonal stay, *C*, affords additional strength. In this instance, the small pulley, *D*, over which the rope travels, is fixed at the out-bye extremity of the knock-off. The full tubs, after being detached from the rope, gravitate down the full-tubs sidings, which have an average fall of $1\frac{1}{4}$ inches to the yard. When the full tubs reach the engine-house curve, *A*, (Fig. 1, Plate VIII.) they are "dragged-up" by a lad (employed for that purpose), who also regulates the feed of full tubs to the shaft-bottom.

The full tubs are run, two abreast, into the cages, which are constructed with double decks. When the snecks are raised, the full tubs push the empty tubs out of the cage; the latter are then pushed on to the empty roads, *E*, by the onsetters, and over automatic lubricators, which grease the bearings of the tubs.

From *E*, the empty tubs gravitate down the empty-tubs sidings, dipping about $1\frac{1}{2}$ inches to the yard, to the hanging-on stations, *H*, where boys are employed in coupling two tubs

together, guiding the rope into the tub-clips, and spacing the pairs of tubs at intervals of 90 feet on the ropes.

An essential feature of the successful working of any system of endless-rope haulage is the proper and careful distribution of the tubs along the rope. For this purpose, a spring-bell, *I*, is fixed at a distance along the roadway corresponding to the distance which must intervene between two sets of tubs; and as the empty tubs pass, they press the spring and ring the bell, warning the boy to attach two more tubs.

If this spacing be not carried out, and the rope be not firmly placed in the clips, the latter may fail to grip the rope, when heavy gradients are encountered; then, a number of tubs may gather together, and the weight, being unevenly distributed along what at all times is a heavily-laden rope, has a tendency to cause the rope to surge on the driving-pulley. Further, the tubs may be derailed, and cause a stoppage of work for a considerable time.

As the rope leaves the driving-pulley, the slack is automatically taken up by a tension-arrangement, *T*, constructed as follows:—A pulley, 5½ feet in diameter, is fixed in a strong frame made of pinewood, fitted with four tub-wheels, *A*, which travel on a railed incline, *B*, dipping slightly away from the rope, there being sufficient travel to allow of the putting in of a splice in the rope should the latter break. The rope passes half way round the circumference of the pulley. An ½ inch chain is attached to the back-end of the tram or bogey, taken under a pulley, *C*, 2 feet in diameter, to prevent the tram from being lifted off the way, and then over another pulley, *D*, of the same dimensions, raised 6 feet above the first-named. Coupled to this chain is a bolt 4 feet long, terminating in a nut, which is loaded with a sufficient number of 100 pounds weights, *E*, to keep the rope taut; and the weights work in a staple, 10 feet deep. As the rope only passes half way round the driving-pulley, it is always advisable to have the tension-arrangement as near to the driving-pulley as possible and convenient, in order to lessen the risk of slip. When in this position, the tension-pulley is placed vertically in the frame (Figs. 9 and 10, Plate IX.) for two reasons:—(1) The excavation necessary for the tram need not be more than 3½ feet wide, and thus the shaft-pillars are not materially weakened, as would be the case

were the tension-wheel placed in an horizontal position, when a much wider excavation would be necessary; and (2) as the full-tubs kips are about 6 feet above the empty-tubs side hanging-on (Fig. 1, Plate VIII.) the rope, after leaving the tension-pulley on the low side, travels along the floor on rollers, where it is out of the way, and does not require to be bound into position for the empty-tubs side hanging-on. Three vertical tension-pulleys, *T*, are erected near the shaft (Fig. 1, Plate VIII.), and these work on the first length of rope passing from the hauling-engine.

Each separate branch-road terminus is provided with a 5½ feet return-wheel for the rope, placed horizontally, so as to slide in a wooden frame, to which it is attached by a ⅝ inch chain (Figs. 11 and 12, Plate IX.). A swivel connects the chain to a screw, 4½ feet long, 2½ inches in diameter, and having 3 threads to the inch. This screw passes through a fixed baulk of timber, and, when tightened up with a nut provided for the purpose, the slack rope in that particular branch is tightened.

The horizontal tension-arrangement, shewn in Figs. 13 and 14 (Plate IX.), can be economically employed farther in-bye where space is of minor consideration, and where the lead of the rope requires an horizontal movement. It is also desirable for use in positions where the tubs are worked on a heavier gradient than prevails at the terminus, as the tightening arrangement shewn in Figs. 11 and 12 (Plate IX.) cannot take up the slack rope automatically.

The wagonway gradients vary from level to a rise and fall of 3½ inches per yard. The main wagonways are made as level as possible, by taking-up bottom-stone and ripping-down top-canches, where necessary. The average gradient is about ¾ inch per yard, falling towards the shaft in the west wagonway; ½ inch per yard dip from the shaft in the south wagonway; and about the same gradient on the north wagonway.

All the wagonways are provided with a travelling-way, 3½ feet wide, and there is 11 inches of clearance between the full and empty tubs.

Telephones are placed at the different junctions, and are found to be exceedingly convenient.

The tubs are attached to the rope, by the Pelton clip (Figs. 5 and 6, Plate VIII.). It is made of mild steel, only weighs 5 pounds, is easily handled, works well, and the cost of its main-

tenance is small. The box, *B*, is attached to the top of the tub by means of the screw, *S*. The clip, *A*, slides out of the box when the cotter-pin, *X*, is withdrawn. When the rope is fixed into the fork, the clip tends to swing on the pin, *P*, thus gripping the rope. The projections on each side of the pin prevent the clip from swinging more than is necessary.

The clips are removed from the empty tubs when the latter arrive at the rope-termini in-bye, and are fixed to the full tubs at the same point; but otherwise they are not removed from the tubs.

Fig. 7 (Plate VIII.) is a sketch of a safety-chock, used on the heavier gradients to catch the tubs, in the event of their being detached from the rope. About 3 feet of new wire-rope is partially twisted round a prop, *A*, and one end is nailed into position; it is then bent, and the other end is fastened to the chock, *C*, made of hard wood, and attached by a bolt to a batten fastened across two sleepers. The rope acts as a spring, and presses the chock against the block; and as the tub passes up an incline, the wheels strike against and open the chock, which immediately falls again into the safety position.

The ropes employed on the haulage-planes are $2\frac{1}{2}$ inches in diameter, and last from 3 to 5 years. Their life varies according to the amount of work that they have to perform. The ropes are made of best plough-steel, with 5 strands and have an iron-wire core, which prevents shrinkage and stretching. This iron-core is cut out of the open strands when a splice is made.

Three methods of conducting the ropes around the curves of the junctions are in use. In one system, three driving-pulleys, *A*, are placed on a vertical shaft upon which the middle pulley alone is keyed fast (Figs. 15 and 16, Plate IX.). The driving-rope coming in-bye from the hauling-engine, passes round this middle pulley, and either of the other two pulleys can be put in and out of gear by the friction-clutch gearing already described. The lower pulley drives the rope in the straight-on wagonway, and the upper pulley works the haulage in the road at right angles to it. The ropes are bound into position by sheaves, as shewn in the sketch. Both full and empty tubs detach themselves automatically from the rope on approaching the junction. The way rises up to the knock-off, *B*, and slopes away to the hanging-on. The kips are constructed with brick

FIG. 5.

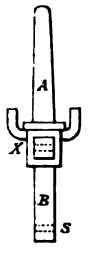
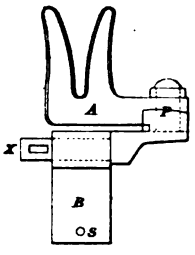
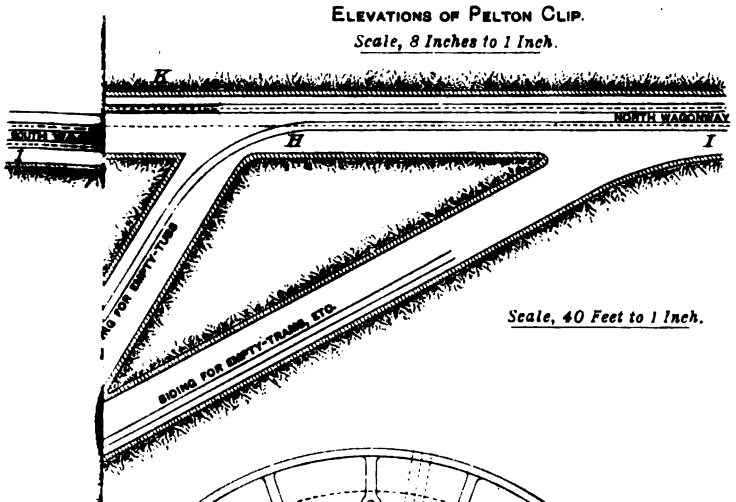


FIG. 6.



ELEVATIONS OF PELTON CLIP.

Scale, 8 Inches to 1 Inch.



Scale, 40 Feet to 1 Inch.

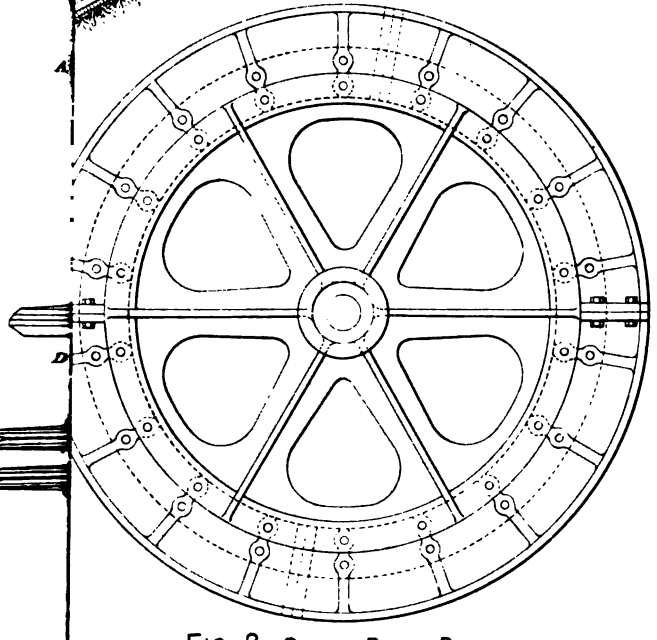


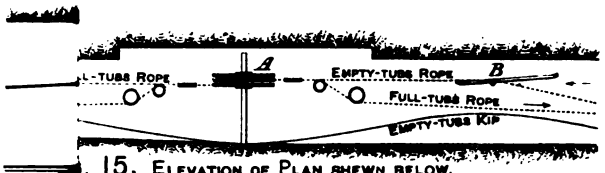
FIG. 3.—PLAN OF DRIVING-PULLEY.

FIG. 4.—SECTION OF DRIVING-PULLEY

Scale, 2 Feet to 1 Inch.

North of E

"...e Haulage at Pelton Colliery."



. 15. Elevation of Plan shewn below.

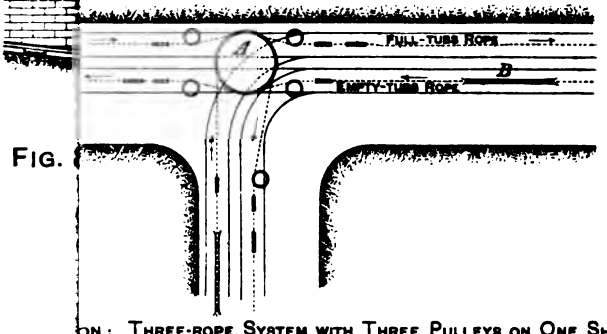
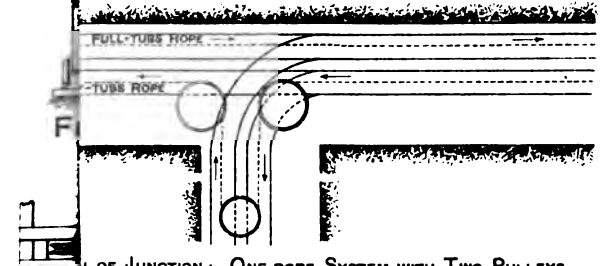


FIG.

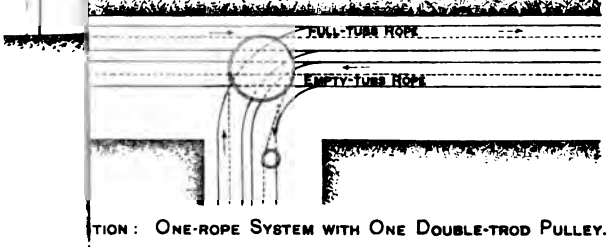
ON: Three-rope System with Three Pulleys on One Shaft.

Scale, 16 Feet to 1 Inch.

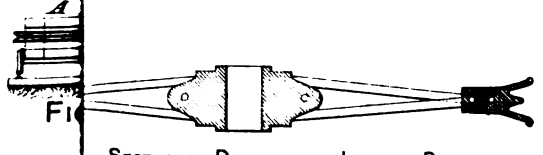


F

OF JUNCTION: One-rope System with Two Pulleys.



TION: One-rope System with One Double-trod Pulley.



F

. Section of Double-trod Junction-Pulley.

Scale, 2 Feet to 1 Inch.

side-walls, filled with ballast, and are raised 2½ feet above the opposite way. Only one of the wagon-ways is worked at once.

Fig. 17 (Plate IX.) shews how a single rope is made to work two roads at right angles one to the other. The rope, in this case, is taken round two wheels at the junction. The tubs are hung on to this rope singly 180 feet apart.

Fig. 18 (Plate IX.) shews an improved method of working the two roads together: only one wheel is erected at the junction, but it is provided with a double trod, as shewn in Fig 19 (Plate IX.) The boss and the trod of this wheel are made of steel, cast round wrought-iron spokes. The empty-tubs rope passes under this wheel to a return-wheel placed in the straight-on wagon-way; thence it returns to the junction-wheel, and passes round the upper groove to the terminus-wheel in the side wagon-way; and then it returns to the junction-wheel, and passes round the lower groove, becoming the full-tubs rope for the main wagonway to the shaft. This is a simple method, easy of construction, and gives good results.

A vote of thanks was accorded to Mr. Thornton for his interesting paper.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
DECEMBER 8TH, 1900.

MR. J. G. WEEKS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on November 24th and that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ROBERT AUTON, Traffic Manager, Birtley, County Durham.
Mr. MATTHEW BARRASS, Colliery Manager, Hedley Hill Colliery, Waterhouses, County Durham.
Mr. WILLIAM BRYHAM, Colliery Manager, Bank House, Wigan.
Mr. GEORGE PLUNKETT CHAPLIN, Mining Engineer, 96, Breakspears Road, Brockley, London, S.E.
Mr. NICHOLAS CHEESMAN, Colliery Manager, Throckley Colliery, Newburn, R.S.O., Northumberland.
Mr. WALTER SPENCER CRASTER, Mechanical Engineer, Craster Tower, Lesbury, R.S.O., Northumberland.
Mr. KINGSLEY DUNBAR-ANDERSON, Mining Engineer, P.O. Box 34, Salisbury, Rhodesia, South Africa.
Mr. WILLIAM FAITHFUL, Mechanical Engineer, Greymouth, New Zealand.
Mr. ALBERT JAMES HILL, Civil and Mining Engineer, New Westminster, British Columbia.
Mr. GEORGE FREDERIC CHARLES HOSKING, Assayer, Helensville, New Zealand.
Mr. WILLIAM PERCY JUSTYNE, Civil Engineer, 5, Norfolk Street, Manchester.
Mr. EDWARD THOMAS ORNSBY, Colliery Manager, 3, St. James' Road, Benwell, Newcastle-upon-Tyne.
Mr. JOHN BONSALL PORTER, Professor of Mining and Metallurgy, McGill University, Montreal, Canada.
Mr. WILLIAM SEVERS, Colliery Manager, The Poplars, Beamish, Chester-le-Street, County Durham.

Mr. Frederick Charles Swallow, Colliery Manager, Nuneaton Colliery, Nuneaton, Warwickshire.
Mr. Claude Leslie Watson, Mining Engineer, Clutton, near Bristol.
Mr. John T. Wilkinson, Colliery Manager, East Howle, *via* Ferryhill, County Durham.

Associate—

Mr. Frank Widdas, Colliery Surveyor, Shiremoor. Northumberland.

Students—

Mr. Geoffry Brandon, Mining Apprentice, Eastfield, Earsdon, Northumberland.
Mr. Harold Sharpley, Mining Student, Bargate, Grimsby.

DEATH OF MR. G. C. GREENWELL.

The President (Mr. J. G. Weeks) said that, since the last meeting, the Institute had lost one of its honorary members—Mr. George Clementson Greenwell, who was President during the years 1878 to 1881 and one of the founders in 1852. His loss was a very great one to all mining engineers, not only in this district but throughout the whole world. He was a man pre-eminent in his position, and his *Treatise on Mine Engineering* was one of the best standard works on the subject. He had contributed many valuable papers on mining and kindred subjects to the *Transactions*, and few engineers had done so much for the advancement of the science and practice of mining. He moved that a letter of condolence be sent to Mrs. Greenwell and other members of the family on the great loss they had sustained, a loss which was shared by the Institute.

Mr. J. L. Hedley (H.M. Inspector of Mines), in seconding the resolution, said that he was intimately connected for many years with their late friend and past President. They had lost a valued member of the Institute and a kind friend, and when he wrote his book on *Mine Engineering*, which had proved so useful to them, it was written, not for his own advantage, but for the benefit of all who took up the profession.

Mr. A. L. Steavenson (Durham) said that he was not one of the original members of the Institute, for he joined it about three years after its formation, but for very many years Mr. G. C. Greenwell was a valued colleague and one whom the members always were glad to hear at their meetings.

The resolution was unanimously adopted.

DEATH OF MR. HUGH TAYLOR.

The PRESIDENT (Mr. J. G. Weeks) said that the demise of Mr. Hugh Taylor had occurred since the last meeting. His work did not lie in the same direction as that of the late Mr. G. C. Greenwell, but he was a member of the Institute from 1856, and was wellknown in the coal trade of Northumberland and Durham. He was kindly and philanthropic, and identified himself with the success which had attended the Northumberland and Durham Miners' Permanent Relief Fund. He moved that a letter of condolence be sent to Mr. Tom Taylor.

Mr. J. H. MERIVALE (Broomhill), in seconding the resolution, said that the late Mr. Hugh Taylor had done a great deal of good in connection with the Durham College of Science. For many years he personally provided for the maintenance and education of 2 or 3 working-men, in order that they might have the advantage of the instruction to be obtained at that College; but the scheme fell through because they could not find young working miners sufficiently well-educated to profit by the opportunity.

The resolution was unanimously adopted.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, BRADFORD, 1900.

The report of the proceedings of the Corresponding Societies Committee of the British Association for the Advancement of Science was read, and also that of Mr. M. Walton Brown, the delegate representing the Institute, as follows:—

NEWCASTLE-UPON-TYNE,
September 15th, 1900.

TO THE PRESIDENT AND COUNCIL OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENTLEMEN,

The meeting of the British Association for the Advancement of Science at Bradford extended from September 6th to 12th, 1900.

Two Conferences of the Delegates of Corresponding Societies were held on September 6th and 11th. The suggestions proposed by the Yorkshire Naturalists' Union respecting the business-procedure of the Conferences were discussed, and finally dropped without being moved.

The subject of the Copyright Bill was then introduced, and after discussion, I moved and Mr. Eli Sowerbutts, representing the Manchester Geographical Society, seconded a resolution, which was passed unanimously, "That the matter of the proposed Copyright Bill be referred through the Committee of Recommendations to the General Committee so far as it affects (1) the copyright of scientific societies in their transactions, and (2) the publication of abstracts of scientific papers; and that they be requested to take such action as will protect scientific societies." I regret to report that this resolution was not sent by the officials to the Committee of Recommendations, and consequently it was not considered by the General Committee. It is self-evident that the procedure of the Conference of Delegates admits of considerable improvement.

The papers of interest to mining and mechanical engineers included the following:—

"Report of the Committee on the Nature of Alloys."

"Ferriferous Horizon in the Huron Formation of Canada." By Prof. A. P. Coleman.

"Flora of the Coal-measures." By Mr. R. Kidston.

"Disposal of House-refuse in Bradford." By Mr. John McTaggart.

"Botanical Evidence bearing on the Climatic and other Physical Conditions under which Coal was formed." By Mr. A. C. Seward.

"Mutual Relations of Iron, Phosphorus and Carbon when together present in Cast-iron and Steel." By Mr. J. E. Stead.

"Origin of Coal." By Mr. A. Strahan.

"Tables of British Strata." By Dr. H. Woodward.

I am, Gentlemen,
Your obedient servant,
M. WALTON BROWN.

The PRESIDENT (Mr. J. G. Weeks) moved that a vote of thanks be accorded to Mr. M. Walton Brown for his services as delegate and for his report.

The resolution was agreed to.

Mr. E. REUMAUX's paper on "The Employment of Iron Bars at the No. 6 Pit, Lens Colliery" was read as follows:—

THE EMPLOYMENT OF IRON BARS AT THE NO. 6 PIT, LENS COLLIERY.

By E. REUMAUX, Managing Director, Société des Mines de Lens; with the Concurrence of Mr. Henri Lafitte, Chief Engineer, and Mr. Th. Havard-Duclos, Engineer.*

After several years of experiments beneath different roofs and under different conditions, the use of iron bars (*allonges en fer*) at the working-faces has been adopted at No. 6 pit, and made compulsory by special rules.

Timbering of Longwall Faces.—The iron bars used in longwall faces are made of ⌶ iron, 4 feet (1·20 metres) in length, as shown in Figs. 1 and 2 (Plate X.). The point in front is made by heating and flattening one end under the hammer, until the two flanges of the ⌶ iron are welded together. A bar weighs about 11 pounds (5 kilogrammes); it can therefore be easily handled, and the cost is less than 1s. 7d. (2 francs).

The method of timbering the face is as follows:—

At the time when a workman is about to commence his cut, there is a row of bars (*rallongues*), each supported by 3 props (*bois de taille*), parallel to and close against the face. These bars are 8 feet 4 inches (2½ metres) long, and must overlap one another sufficiently so that the first prop, *Y*, of one bar shall be in the same line, at right angles to the face, as the last prop, *Z*, of the preceding bar (Fig. 3, Plate X.).

The workman, commencing to scallop, clears the roof before him, and would soon be underneath unsupported ground, were it not for the iron bars. As soon as he has stripped 12 inches (0·30 metres) of roof, he slips an iron bar, *D*, between the roof and the last-placed bar. But for this purpose, he must have prepared a place for its insertion; and, consequently, above each prop supporting the bar, the workman must place a large wooden wedge (*coin*), *F*, which he should, moreover, do in order to tighten up the timber (Fig. 4, Plate X.).

* Translated by Prof. Henry Louis, M.A.

Fig. 4 (Plate X.) shows the reason for making the chisel-shaped end on the iron bar; and it is evident, that if it had not been thus formed, there would not be contact between the roof and the iron bar when hewing is commenced. The workman consequently places the iron bar with the web vertical and the chisel-edge upward. As soon as any of the roof is bared by the removal of the coal, the workman must advance his iron bar, *D*, and tighten it against the roof by means of the wedge (*coin de serrage*), *K*; and it is generally required that the iron bar shall never be more than 8 inches (0·20 metre) distant from the coal-face.

Each workman is supplied with three iron bars, which he advances successively in front of him, 1 foot 8 inches (0·50 metre) apart. When he has driven 3 feet 4 inches (1 metre) forward, the iron bars still project behind the bar, *B*, at least 16 inches (0·40 metre), and can still be firmly fixed by the wedge, *K* (Fig. 6, Plate X.). The workman must now insert a wooden spile (*queue*), *G*, alongside his iron bar, driving it forward to the coal-face and supporting it by a temporary prop (*tintiat*), *H*. Spiles are then inserted adjacent to the two other iron bars, then all three are withdrawn, and coal-getting is continued on either side. Consequently when the workman has finished his stint he has behind him a bar, upon which are placed 6 spiles supported by 6 temporary props (Figs. 7, 8 and 9, Plate X.). At this point, the workman gets another bar (*rallongue à mettre*), and after having fixed it firmly against the roof by means of the three props, which he is compelled to set, he removes the 6 temporary props (Fig. 9). He will then have worked his entire cut, without having been a single moment beneath unsupported roof.

It should here be observed that the length of the iron bar, fixed at 4 feet (1·20 metres), is justified by the reason given above: namely, that a butt end of 16 inches (0·40 metre) shall remain, in order to enable it to be kept firmly in place when it is driven forward; and that the chisel-shaped point is useful, not only for supporting the first few inches of unprotected roof, but also to make it easy to insert and withdraw an iron bar, 4 feet (1·20 metres) in length, between the two rows of longitudinal bars, 3 feet 4 inches (1 metre) apart.

The preceding description is purely typical, and only serves to exactly indicate the principle of the employment of the iron

bars, but this system has considerable elasticity and may be applied to any working-place either rising (*taille montante*) or level (*taille chassante*), whether the roof is good, bad or indifferent.

Timbering of Gateways.—Iron bars are also used in the driving of roadways made in the roofstone. The stonemen (*coupeurs de mur*) have 3 iron bars, 1½ inches (4 centimetres) square. These are somewhat heavy, and it is intended to replace them shortly by iron bars of the same type as those which are used in working the coal; the only difference will be in the length, experience having proved that the iron bars used by stonemen should be 5 feet (1·50 metres) long.

As soon as the shot is fired they are used in the same manner as the others. The stoneman drives his three iron bars over the last balk (*bille*), and pushes them forward in proportion as he removes the ground, so as to be always protected (Fig. 10, Plate X.).

As additional conditions of safety, we insist that after having set his timber (*bille, bois de fond* and *bois de voie*), the workman shall pack the face, and that he shall connect the bar (*rallongue d'abindage*) supporting the edge of the stone by means of strong struts (*poussards*) to the last set of timber; and, finally, the first thing in the morning, the worker in coal must place a supplementary bar (*rallongue supplémentaire*), 8 inches (0·20 metre) in advance of the bar (*rallongue d'abindage*) set on the previous day.

Results.—The experience of several years has proved that the employment of iron bars has reduced in very marked proportions the number of accidents caused by falls of stone or of blocks in the working-places; and the decrease in the number of injured persons from this cause certainly exceeds 50 per cent.

REFERENCES TO PLATE X.

A and B	Rallongue ...	Bar.	*G*	Queue	Spile or pole.
C	Rallongue à mettre ...	Bar.	*H*	Bois d'attente or tintiat ...	Temporary prop.
D	Allonge en fer	Iron bar.	*K*	Coin de serrage	Wedge.
E	Bois de taille	Prop.	*L*	Bille	Balk.
F	Coin	Wedge or bridge-chock.	*M*	Bois de voie ...	Prop.
			N	Bois de fond ...	Prop.

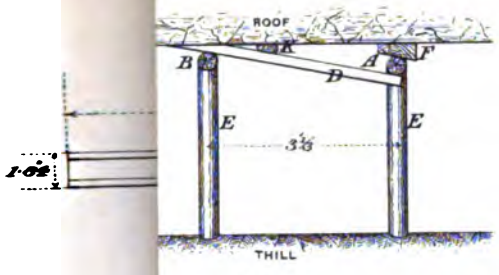


FIG. 4.

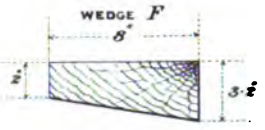


FIG. 5.

Scale, 10 Inches to 1 Inch.

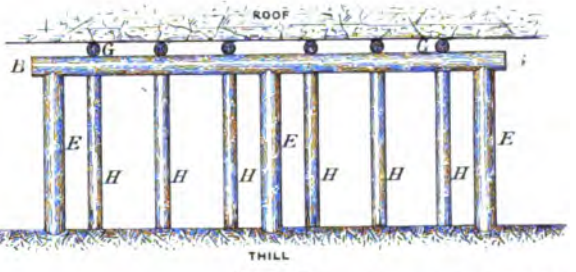
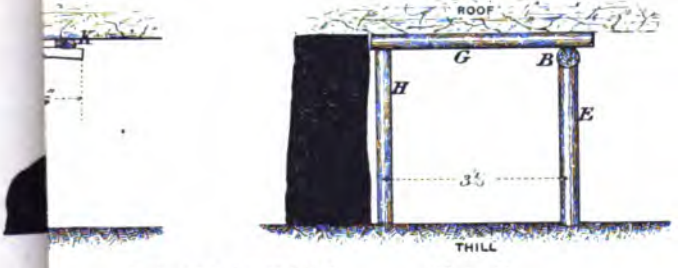


FIG. 9. Scale, 40 Inches to 1 Inch.



Scale, 40 Inches to 1 Inch.

FIG. 7.

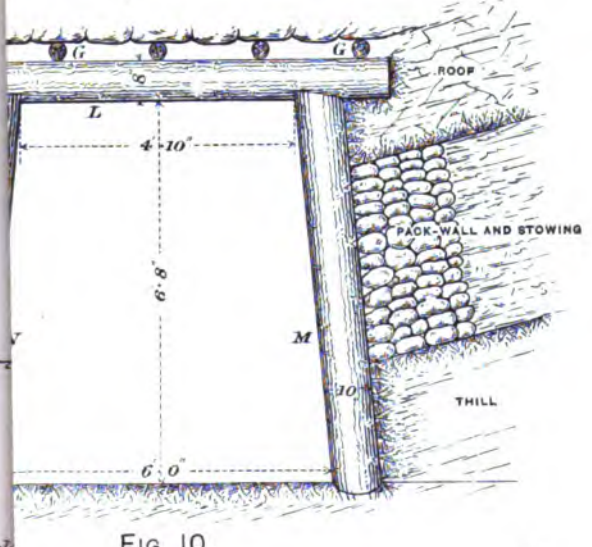


FIG. 10.

North of Engl[illegible]

VOL. L, PLATE VII.

Mr. A. L. STEAVENSON (Durham) said the paper was interesting and useful to those who had to deal with bad ground, but in the North of England they had such roofs as would render the use of a system of that character quite unnecessary. He thought that the system was a resuscitation of the old Cornish method of "fore-poling." On one occasion, he had to drive through a quicksand in Cleveland, and he obtained the services of some Cornishmen, who were used to this method, and they drove the drift successfully. He suggested, however, that the word "spile," which had been used in the translation, should be "pile"; thus sinkers in this district always referred to "piling" through sand.

Prof. H. LOUIS said that in the Alston district, the miners universally spoke of "spiling"; and for many years he had understood the word to be used as the equivalent of fore-poling, piling being somewhat different. The word "spile" was used by standard writers, such as Dr. C. Le Neve Foster in his *Text-book of Ore and Stone-mining*; and by Messrs. J. L. Hedley and W. Leck in their paper on "Timbering in the Iron-ore Mines of Cumberland and Furness."* He (Prof. Louis) looked upon the operations of "piling" and "spiling" as being somewhat different in execution, although no doubt similar; and he thought that pile and spile (often written also spill) were even etymologically distinct. Dr. Skeat gives as the probable derivation of pile the Latin *pilum*, a javelin; and for spill the Teutonic *spelda*, a splinter; the *Century Dictionary* derives spile from the Danish *spijl*, a beam or bar.

Mr. J. H. MERIVALE said that Mr. Reumaux had omitted the important consideration of cost in his paper. Mining engineers all agreed that, where human life was concerned, cost was a matter of secondary importance; but in considering any new method of timbering they must also consider the cost.

Mr. J. L. HEDLEY (H.M. Inspector of Mines) asked whether it would not be desirable to adopt the system at mines in this district, even where the roof was good.

Mr. W. C. BLACKETT (Durham) remarked that the present paper, like Dr. C. Le Neve Foster's, contained little information

* *Trans. Inst. M.E.*, vol. xvi., page 281.

as to the actual conditions under which the system was adopted. For instance, the condition of the roof was not referred to, one of the most important considerations when they were asked to adopt extraordinary methods of timbering. It should not be assumed, however, that such methods were not adopted in this mines-inspection district, for precautions of the kind were taken at once whenever the ground became sufficiently bad, and it was not necessary for mining engineers to go to France or any other country to be taught how to pile through broken ground.

Mr. T. E. Forster (Newcastle-upon-Tyne) remarked that one of H.M. inspectors of mines going to Cleveland and seeing Mr. Steavenson driving through quicksands with piles might with equal reason want them to apply the same method to all parts of the United Kingdom. With all deference to Mr. J. L. Hedley he thought that the inspectors of mines themselves should consider whether it would be desirable to adopt the Courrières method of timbering in this district. It would not take much consideration on the part of the mining engineers to decide that it was not necessary, with a good roof, to adopt the system recommended by the Home Office.

Mr. J. L. Hedley was quite sure that if the mining engineers of this district considered that the adoption of the Courrières system would be conducive to saving of life they would also adopt it in the case of good ground.

Mr. R. A. S. Redmayne (Seaton Delaval) endorsed what had already been said by previous speakers respecting the conditions of roof and the unsuitability of the method in the North of England, except in the case of bad roofs, and then it had been adopted in many instances before ever they had heard about the application of the method at the Courrières collieries. In a case at the collieries, where he was engaged, they had used an egg-ended boiler (with the ends removed) which was forced through the debris of an extensive fall of roof by hydraulic pressure, but surely that did not imply that every other colliery should support their roads by means of egg-ended boilers forced into position by hydraulic pressure! If they troubled to take out the figures it would be found that fatalities from falls of ground at the face in this district were practically *nil*; such accidents as had happened at the face arose principally from falls of side, or of coal, or while drawing timber.

Mr. S. HARE (Ravensworth) said there appeared to be some confusion of terms in comparing spiling or piling with fore-poling or running timber. He had always understood that a spile was made of iron, or of wood pointed with iron, and that it was driven in front of the working-face. Fore-poling is commonly used in Durham and Northumberland, but with this difference from the Courrières method that wooden planks were used instead of iron bars: he thought that the former were equally as good as, or better than, the latter, because they afforded a better support to the roof than iron bars. About a year ago, he was using this system in a narrow place, and the running planks were supported by baulks. The top was bad, and on a shot being fired, the coal fell, knocked out the supporting timber and baulk, and the baulk came down on the top of the man, who was killed. This class of accident would follow on the use of timber or iron supported at one end only; and, in shooting seams, there would be danger of the iron bars being forced out, or of the props supporting them being canted over.

The PRESIDENT (Mr. J. G. Weeks) remarked that the discussion shewed that the Courrières system of iron bars was not a new system, as far as this district was concerned, and they had the further evidence that they were familiar with this question, in Messrs. J. L. Hedley and Leck's paper, read some years ago.* Mining engineers applied the system where it was necessary, but the Home Office proposed that they should apply the system in every mine. It appeared to him that this was equivalent to saying that, because they had a piece of bad ground in a roadway and put in 100 feet of brick-arching, they should arch all of the roads from the shaft to the coal-face. He thought that the circumstances of each mine should decide the question, and from his knowledge of the mining engineers of the North of England he knew that they would adopt the Courrières or any other plan if they thought it necessary for the saving of life. There were collieries within 10 to 12 miles of Newcastle, which had worked for many years without any deaths from falls of ground, and it would be equally logical for the Home Office to recommend that they should adopt the methods in use at those collieries, yet this was what they were doing. It was surely not necessary to go

* *Trans. Inst. M.E.*, 1898, vol. xvi., page 281.

farther away to ascertain what successful timbering and efficient supervision would assure. He observed that the iron bars were used only at the No. 6 pit of the Lens collieries, and possibly they were adopted in that particular case because the roof was exceptionally bad.

Mr. H. F. Bulman (Burnopfield) wrote that he visited the Courrières collieries in October last, and went down the No. 3 or Méricourt pit to the Saint Cécile coal-seam, at a depth of 1,070 feet. This seam varies in thickness from 3¼ to 5 feet (1 to 1½ metres), averaging, say 4 feet of coal; and, where he saw it, it lies at an inclination of about 1 in 18. It was worked on the longwall system with a stepped face, each bank or stall being about 45 feet wide. Three men work in each stall, each of whom is provided with 3 iron bars. In ordinary practice, these bars are inserted as soon as the coal-face has advanced 20 inches (50 centimetres), beyond the timber, that is, half the distance between the rows of props. The roof in the working-places visited was a good shale, falling readily in the goaf behind the timber, and apparently not giving much trouble at the face. The back timber was being drawn. Where this is done, the rule is to insert an extra row of timber, so that the two rows next the goaf are only 20 inches (50 centimetres) apart instead of 3 feet 4 inches (1 metre). The sizes of the timber were as follows:—Props, 2½ to 3½ feet long were 10 to 12 inches in girth; 3½ to 5 feet long, 12 to 14 inches in girth; and 5 to 6½ feet long, 14 to 16 inches in girth. The head-pieces (*rallongues*) running parallel to the coal-face, were about 8½ inches in girth, and the smaller pieces (*queues*) at right angles to these, 5 inches round. This timbering is put in systematically at intervals of 3¼ feet (1 metre) apart (with the exception mentioned, where the back timber is drawn), irrespective of the nature of the roof, and where the roof is bad, additional cross-pieces are put in between the others. The Courrières Company hold an area of coal-property of 21 square miles, and are raising nearly 2,000,000 tons yearly from 8 different seams. In a portion of their concession, the strata are contorted, the seams being bent over on themselves, so that the floor becomes the roof.* The circumstances therefore point to a considerable variety of roof. Naked lights are in use throughout. He understood that

* *Trans. Inst. M.E.*, vol. iii., page 1,028.

the cost of timbering was much the same as it was 20 years ago, when the death-rate from falls of ground was about 5 times as great. The general cost of timbering at collieries in the Pas-de-Calais district was said to be about 8d. (70 to 85 centimes) per ton.

Mr. M. Walton Brown, in proposing a vote of thanks to Mr. Reumaux for his interesting paper on the use of iron-bars at the Lens collieries, said that the members had been allowed to visit these collieries, some years ago, and had examined with interest the novel appliances adopted by Mr. Reumaux and his colleagues. The Lens collieries produced over 3,000,000 tons of coal a year, from a mineral concession of about 27 square miles, containing 55 workable coal-seams with a mean thickness of 2 feet, and about 11,000 workpeople were employed. The seams are usually worked on the longwall system, the winning heading or gateway being usually driven to the rise, and gateways are either driven level (*tailles chassantes*) or are driven, from level cross-gateways, to the rise (*tailles montantes*). The gateways and cross-gateways are driven from 40 to 50 feet wide on the level or to the rise of the seam, and the faces are stepped about 30 feet apart. If this system of timbering, with bars placed parallel and close to the longwall-face, and props, without caps or lids, be adopted in this country, the hewer will be prevented from blasting, as it will be difficult to commence to hole under the coal, with props placed about $3\frac{1}{3}$ feet apart and close to the coal-face (Fig. 3); or to bore a shot-hole near the roof, with bars, poles and bridge-chocks placed close adjacent to the face (Fig. 8, Plate X.). It is difficult to conceive that the Home Secretary has been advised by the majority of H.M. inspectors of mines, that a man will work in greater safety, when scalloping than when blasting coal, after making a proper jud. When scalloping, he is arduously removing the coal, for some hours under the same roof; but when blasting, the coal is supported, at close intervals, on sprags, until it is holed under, it is then quickly dislodged by an explosive, and it is only when the hewer is actually filling his coal (should he fail to immediately set temporary props) that he undergoes risk of accident from falls of stone. Pack-walls are built at the sides of the gateways and cross-gateways and at regular intervals in the goaf, which is also tightly stowed with stones, brought from other parts of the mine or from quarries on the surface, if

necessary. It is not usual to draw the timber at the Courrières collieries, and the adoption of such a wasteful method would probably promote underground fires in many British collieries. Mr. H. F. Bulman stated that the roof is usually shale, "falling readily in the goaf,"* and possibly it rarely happens that the shale falls in pieces of sufficient size to injure a workman. The shale is usually overlain with beds of strong sandstone. The workings of the Lens and other collieries in the Nord and Pas-de-Calais districts of France, are in unworked coal-fields, and being developed downwards in successive stages, the roofs of the seams will necessarily be more stable than the roofs of many of the seams, now being worked in this district, over exhausted seams. Mr. Bulman had mentioned that the thill, from the inversion of the Coal-measures, sometimes becomes the roof.† The thill is usually a hard, jointed fire-clay, full of slips or backs, difficult to detect, and requiring minute examination, where it forms the roof, as jowling with a pick usually conveys a delusive idea of strength. It is a matter for conjecture whether the safety of the system of timbering is not partly due to the fact that all timber is set by the hewer, as directed by an official, before he leaves his working-place.

The vote of thanks was cordially approved.

DISCUSSION OF MR. W. H. HEPPLEWHITE'S PAPER ON "THE HEPPLEWHITE TAPERED PIT-PROPS AND BARS."‡

Mr. T. E. Forster (Newcastle-upon-Tyne) said it might be well that the members should be informed that the proprietors of the Hepplewhite patent were prepared to take action against any persons using tapered props without their license.

Mr. W. O. Wood (South Hetton) said that the tapering of pit-props was by no means new. In 1878 and 1879, he used tapered pit-props extensively in the longwall workings of the Harvey coal-seam at East Hetton colliery. Their use was attended by some economy, and where head-trees were used,

* *Trans. Inst. M.E.*, vol. xx., page 212.

† *Ibid.*, vol. iii., page 1,028; and vol. xx., page 212.

‡ *Ibid.*, vol. xix., pages 8 and 106.

which did not cover the whole surface of the prop, the tapering was an advantage, as it prevented the props from splitting; but where head-trees were not used, the saving was less than was expected. The ends of the props soon "bushed," and the props rapidly became too short for use. The cost of tapering was considerable, it was found that the economy was very trifling, and the system gradually fell into disuse. The system that he had found most useful was to chamfer the top and bottom of the prop, and to place an iron collar round each end of the prop.

Mr. M. Walton Brown (Newcastle-upon-Tyne) remarked that the amount of roof-pressure varies according to the method adopted for the removal of coal, and the thickness and nature of the overlying strata. Under precisely similar circumstances it was evident that if 100 untreated props, with a breaking-load of 30 tons, were in use in a district, it would require 200 tapered props, which "bushed" at a pressure of 15 tons, to support the same area of roof. The consequent economy, if any, arising from their use depended upon the frequency with which the tapered props were bushed, the cost of tapering, and the labour of setting the additional number of props required to support the roof. Tapered props were unsuitable for use in thin seams, as they would allow the roof to settle, and prevent the passage of the tubs, and from practical experience it was not desirable to taper props, less than 16 inches in girth at the small end.

Mr. W. C. Blackett (Durham) said that tapered props were used in the Four-feet coal-seam in South Wales, and in other districts many years ago. The ends were cut wedge-shaped, which served the purposes of gradually receiving the full weight of the roof, of allowing the prop to yield a little, and to force itself into the bottom. He could not see how so old a method could be patented, but possibly the machine which sharpened the props was patented, although it was in principle similar to a pencil-sharpener.

Mr. W. Hutton Hepplewhite (H.M. Inspector of Mines) wrote that Mr. W. O. Wood's statement as to his use of tapered pit-props was conflicting as to their economy, and utility. Mr. W. O. Wood stated that "the tapering of pit-props was by no means new"; that "he used tapered pit-props extensively" and that "the economy was very trifling." Mr. Wood also stated

that "where head-trees (which he understood meant some kind of lid on the top of the prop) were used, which did not cover the whole surface of the prop, the tapering was an advantage as it prevented the props from splitting." From his (Mr. Hepplewhite's) experience, he would have expected the opposite to occur, because a lid which did not cover the whole surface of the prop would certainly be squeezed into it and split it in the middle or on each side. Further, Mr. Wood stated that "where head-trees were not used, the saving was less than expected." Surely Mr. Wood did not expect more economical results from props set, without some kind of head-trees (that is, props set bare between roof and floor) than props set with lids or head-trees. He had always understood that lids or head-trees were used to save the props from being broken when the "weight," that is the pressure of roof, came on, while bare props would probably bore into a soft shale roof and weaken the stone. The cost of tapering did not exceed ½d. per prop, whether done by a tapering-machine, circular-saw, or by hand. The economy of using Hepplewhite tapered prop over the old round end had been practically demonstrated to be at least 50 per cent., and this was considerably at variance with Mr. Wood's alleged experience of tapered props. By placing an iron collar round each end, the prop would practically become perfectly rigid, as the ends would be prevented from "giving" when subjected to pressure; and consequently, when set in a mine with a small depression of roof, a central fracture would be produced at the first time of setting. In such a case, the tapered prop would yield and shorten with the pressure, and at the same time be supporting the roof. The cost of chamfering, and ringing each end of a prop, must be heavy compared to the value of the prop, and could not add less than 6d. to the cost of the prop. The economy is so manifestly obvious that further comment is not needed.

He would like to direct Mr. Walton Brown's attention to Table I. in his paper, showing the depression of roof in various seams.* It was a mistake to suppose, or assume, that the number of tapered props required to support the same area of roof was double the number of ordinary props. The untapered prop shows a central fracture when subjected to 34 tons of vertical pressure, and the tapered prop shows signs of "burring" at the tapered

* *Trans. Inst. M.E.*, vol. xix., page 13.

bottom-end at 15 tons. Such props, when set side by side in a working place, or under the hydraulic press, with the load gradually applied, would show that the untapered prop had received the full pressure of 34 tons, while the tapered prop had only received 15 tons, because the tapered end was yielding and shortening, while the untapered prop, having no part relatively weaker, succumbed with a central fracture. The subsidence of the roof is gradual, imperceptible, and almost irresistible, and it will continue to settle in the back goaf or waste until it becomes solid, despite the use of pack-walls or props. The aim and principle of the Hepplewhite tapered prop is to yield to this irresistible pressure, consistently with sufficient strength in the tapered end to support local stone, and rendering the working-stall infinitely safer for the workmen than when filled with broken, useless props. He was of opinion that the use of tapered props in thin seams would be found preferable to ordinary pit-props, because there would be no broken props bulging into the tram-roads and obstructing the passage of tubs and workmen. He did not favour props of a less girth than 16 inches, being tapered.

He could only state from practical experience, where soft floors occurred, that the difficulty of preventing broad-ended props from entering, and often allowing the roof to fall, was exasperating, without having recourse to chisel-shaping the end to assist its penetration; but Mr. W. C. Blackett should not confuse the chisel-shaping of props for penetration into a soft floor, with the tapering of props intended for use on hard floors.

Mr. Hugh Ross read the following description of "A Method of Boring Deposits out of Rising-main pipes in Shafts":—

A METHOD OF BORING DEPOSITS OUT OF RISING-MAIN PIPES IN SHAFTS.

By HUGH ROSS.

At collieries where pumps are employed difficulties occur from the deposition of solid matter in the delivery-pipes; and the writer will describe a method adopted at Croxdale colliery for the removal from pipes of a sediment of extraordinary hardness, expeditiously and at little cost.

Pumping Plant.—There are two lifting sets, 19 inches in diameter, at Croxdale colliery. The bottom set lifts the water 330 feet, delivering it into an under-level drift, and the top set lifts it 270 feet, from the under-level drift to the surface.

Time of Deposition.—In October, 1892, the bottom set of pipes became furred to such an extent that the spears stuck fast in the pipes, and it was impossible to draw them unless the pipes were drawn to the surface at the same time. Consequently, the pipes and spears were drawn, and 7½ days of continuous working were spent in sending the pumps singly to the surface, and in cleaning and replacing them in position. The colliery was idle during the whole of this time, and water was gathering in the standage and workings.

In September, 1899, it was discovered that the deposit was again rapidly closing around the spears; and it was at once decided to remove the deposit with a boring-tool. The writer was aware that similar work had been carried out successfully at Hebburn colliery,* but owing to the exceptional hardness of the deposit at Croxdale colliery he was of opinion that the system adopted at Hebburn was unsuitable.

* *Trans. Inst. M.E*, vol. iii., page 113.

Details of Tool.—The tool shewn in Figs. 1, 2 and 3 (Plate XI.), was designed: it consists of an end cut from a pipe, A, having an unusually strong flange. A steel plate, B, with its outer edge turned downward so as to act as a chisel, is bolted to the flange of the pipe. In addition, three rings of chisels are inserted, six in each ring. The outer ring of chisels, C, 2½ inches long, are attached by bolts to the steel plate and the flange of the pipe, and are made from the steel of locomotive springs. The chisels in the second ring, D, are made of steel, 1¼ inches square and 4½ inches in length, and are studded through the steel plate into the flange of the pipe. Those of the inside ring, E, are also made of steel, 1¼ inches square, and 6 inches in length, and they too are studded through the steel plate into the flange of the pipe. The chisels were all heated to a bright cherry red, so as to give them the requisite hardness, durability, and elasticity. The complete tool weighs 400 pounds. A chain, F, weighing 160 pounds and 40 feet in length, was suspended below the tool, for the purpose of assisting in the removal of the sediment from the pumps. Sufficient rotation of the tool was secured by the twisting of the rope, R, which was an old plough-steel haulage-rope (Lang lay).

Mode of Operation.—It occurred to the writer that the crusher-engine, G, could be utilized in conjunction with the jack-engine, H, to work the boring-tool, A (Fig. 4, Plate XI.). The jack-engine was used for lowering the tool slowly, and almost continuously, as it cut its way through the deposit in the pumps. The whole arrangement was so evenly balanced that the weight of the tool carried the drum, I, of the jack-engine slightly around at each stroke, so that it was but seldom necessary for the engine-man to handle the crusher-engine, G, unless the rope became slack.

The crusher-engine, G, was used for giving the boring-tool the necessary percussive action. The length of stroke of this engine is 28 inches, which was not considered sufficient fall for the boring-tool. A hanging pulley, K, on a loose spindle, was suspended over the drum of the jack-engine, the rope, R, from the drum of this engine was taken over it, and the rope, S, from the crusher-engine was attached as shown in Fig. 4. By introducing this pulley, the desired length of drop and speed was obtained for

the boring-tool, thus making the fall of the tool equal to about twice the length of stroke of the crusher-engine, and its speed equal to twice that of the crusher-engine, and in this way the tool had a smart drop.

When the boring arrangement was ready for work, the spears were again found to be fast in the pumps, and a few of the pipes had to be drawn to the surface before the spears could be drawn. The tool was then started at its work, and it cut its way through the deposit in the remaining pipes at the rate of 22 feet per hour, with the crusher-engine running at 24 revolutions per minute. The whole arrangement worked smoothly and gave no trouble. Five workmen were required to carry on the work: one man at the jack-engine, lowering the tool; one man at the crab-engine raising the débris to the seam with a kibble; one man filling the débris into the kibble at the bucket-door; another man emptying the kibble at the level of the Brockwell seam; and another man waiting-on in the shaft at the top of the set of pumps, watching the tool at work.

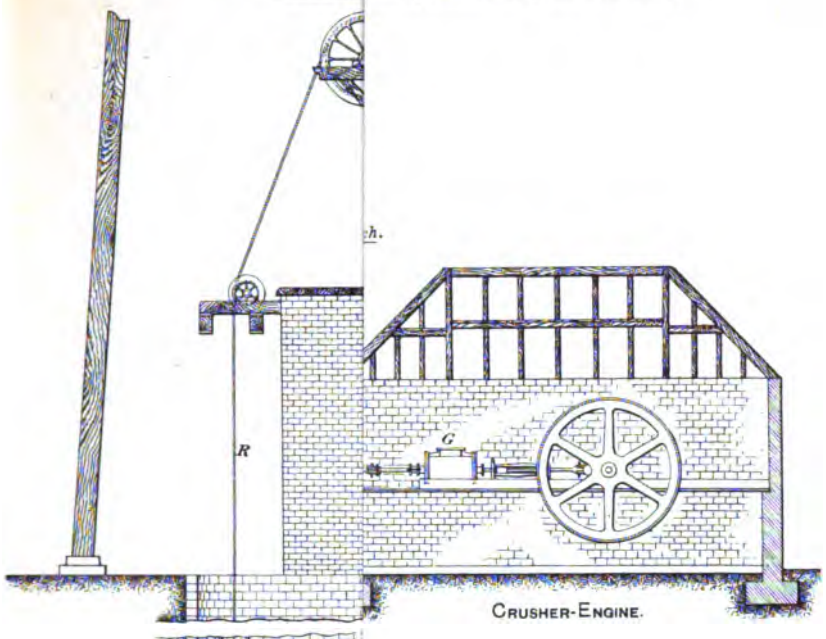
Comparison of Methods.—In 1892, when the whole of the pipes were withdrawn to the surface and cleaned, the cost of labour alone was about £100, and if the loss due to the colliery being off work for 7 days be added, the total cost would amount to a very considerable sum.

The writer estimates that, in future, the 330 feet of pumps can be cleaned with this boring arrangement in about 15 hours, during a week-end, without interfering with the working of the colliery, at a cost of about £6, which includes the cost of fitting up the boring arrangements, but does not include the cost of drawing, cleaning, and examining the spears.

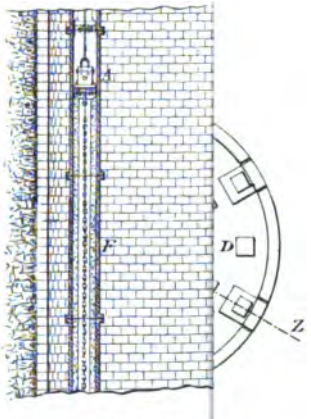
Nature of the Deposit.—The sediment cleaned out of the 330 feet of pumps weighed 18 tons, and was of so hard a nature that it could only be separated from the pumps by means of hammers and chisels. The hardness of the deposit is 5·2, on the Mohs scale of hardness of minerals. The deposit has the following percentage composition:—

Carbonate of Lime	78·5
Siliceous Matter	18·5
Iron and Alumina	0·8
Moisture	2·2

"To illus Rising-main Pipes in Shafts."



CRUSHER-ENGINE.



Scale, 12 Feet to 1

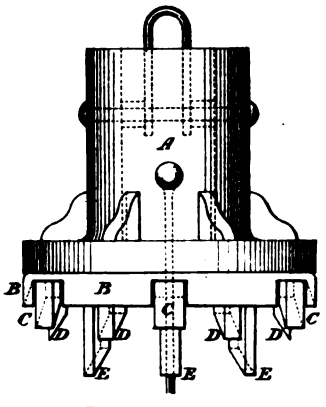


FIG. 1.—SIDE VIEW.

Scale, 1 Foot to 1 Inch.

removed about once a year there would be less friction, and the pumps would be more effective in their working.

Mr. C. C. LEACH asked whether any note had been taken of the power required when the pumps were choked with the deposit.

composition:—

Carbonate of Lime	78·5
Siliceous Matter	18·5
Iron and Alumina	0·8
Moisture	2·2

The pit-water contains 285·0 grains of mineral matter per gallon, and 140 grains of chlorine per gallon, equivalent to 230·8 grains of common salt.

Advantages of the System.—By this method the deposit can be removed from the pumps in position in shafts, irrespective of the hardness of the sediment. Moreover the removal is effected with appliances already existing at any colliery, it is done in a comparatively short period of time, avoiding any stoppage of coal-drawing or long cessation of pumping operations, and at a trifling cost.

Mr. A. L. STEAVENSON (Durham) said that in Cleveland, where the water deposited a large amount of irony matter, they had a pipe about 1 mile long to convey water from the rise workings, and this pipe was furred up in such a way that it was difficult to clean it until he got a machine, which he believed was known as a "fish;" it was about 3 feet long, and was fitted with a cutting head and a cutting tail. This machine was placed in the pipe at the top end, and the stream of water carried the "fish" along, until in a very short time it came out at the bottom end of the pipe, clearing away all the deposit.

Mr. Ross, replying to questions, stated that the deposit in the pipes was about 5 inches thick. It did not adhere much to the spears, which were drawn out occasionally and cleaned. The water came from the Brockwell and Busty coal-seams. It would be a mechanical economy to clean the pipes more frequently. If anything, the scale was harder on the inside than against the pipes. There was no grit in the sediment, and the chisels were not much blunted.

The PRESIDENT (Mr. J. G. Weeks) said that there might be some chemical action between the pipes and the deposit to account for the latter being rather soft near the pipes. If the scale was removed about once a year there would be less friction, and the pumps would be more effective in their working.

Mr. C. C. LEACH asked whether any note had been taken of the power required when the pumps were choked with the deposit.

Mr. Ross said that the pump was run slowly and the effects were not very marked. They had no means of testing the pressure of the water at the pump-bucket.

Mr. S. HARE (Ravensworth) said that he was personally very much indebted to the writer of the paper, for he was experiencing some difficulty at his colliery, where they had two sets pumping with only about $\frac{3}{4}$ inch clearance between the deposit and the spears, and there was practically no water-standage. His great difficulty was how to remove the deposit from the pipes without flooding the pit. He had made experiments to ascertain the loss of efficiency of the pump owing to the deposit, and although it was difficult to measure the exact quantity of water pumped, owing to the position of the delivery-drift, he calculated that the loss was at least 20 per cent. The buckets speedily wore out owing to the excessive pressure.

Mr. M. WALTON BROWN said that the following papers had been read on methods of removing deposits from pipes:—"The Hydraulic Internal Scraping of the Torquay Water-main," by Mr. R. E. Froude, *Report of the British Association for the Advancement of Science*, 1869, pages 210-211. "Mechanical Scraper for removing Incrustation in the Mains of the Torquay Water-works," by Mr. John Little, *Proceedings of the Institution of Mechanical Engineers*, 1873, pages 216-232. "The Internal Corrosion of Cast-iron Pipes," by Mr. Mathew Buchan Jamieson, *Minutes of Proceedings of the Institution of Civil Engineers*, 1881, vol. lxv., pages 323-336. "Lancaster Water-works Extension," by Mr. James Mansergh, *Minutes of Proceedings of the Institution of Civil Engineers*, 1882, vol. lxviii., pages 253-277 (258). "The Cleansing of the 6 Inches Main of the Omagh Water-works," by Mr. J. H. Swiney, *Transactions of the Institution of Civil Engineers of Ireland*, 1887, vol. xix., pages 20-33. "The Removal of Corrosion from Water-mains," by Mr. Herbert Henderson, *Minutes of Proceedings of the Institution of Civil Engineers*, 1894, vol. cxvi., pages 307-310. "The Scraping of Water-mains," by Mr. John Barr, *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, 1897, vol. xl., pages 200-222. "The Incrustation of Iron-pipes at the Torquay Water-works," by Mr. William Ingham, *Proceedings of the Institution of Mechanical Engineers*, 1899, pages 479-525.

The PRESIDENT (Mr. J. G. Weeks) moved a vote of thanks to Mr. Ross for his interesting paper.

Mr. T. E. FORSTER seconded the resolution, which was cordially approved.

Capt. C. C. LONGRIDGE's paper on "Dry and Wet Treatment of Copper-ores" was read as follows:—

DRY AND WET TREATMENT OF COPPER-ORES.

By Capt. C. C. LONGRIDGE.

The information collected in this paper covers—Ore-reduction and concentration; methods and chemistry of calcination; chemistry and systems of smelting; refining; choice of slags; blast and reverberatory furnaces; and lastly, extraction by wet processes.

1.—Reduction and Concentration.

The first step in the treatment is the reduction of the ore to the size most suitable for subsequent operations. On an average, mining furnishes mineral, consisting of 55 per cent. of coarse ore (all sizes down to 1 inch in diameter); 25 per cent. of medium or ragging ore (pieces from ¼ inch to 1 inch in diameter); and 20 per cent. of fines (particles below ¼ inch in diameter).

For all purposes, except reverberatory smelting or wet treatment, it is desirable to avoid, as far as possible, any increase in this amount of fines. Hand-breaking, therefore, is often preferable to machine-reduction, since the former gives less, and with some ores, nearly 50 per cent. less fines than the latter. It has also a further advantage, for in hand-reduction, the workman is able to pick out barren lumps, and thus raise the copper-contents of the product; effecting thereby, in subsequent treatment, an economy which perhaps many times covers the greater cost of hand-spalling. As regards output, a skilful workman dealing with coarse and medium ore, as it comes, will break 7 tons (2,000 pounds) per 10 hours shift, to a diameter of 2½ inches, and, in some cases, will help to screen and load the same. With labour at 6s. 3d. per day, the average cost of spalling is about 1s. 4d. to 1s 5d. per ton, everything included.

When machine-crushers are used, they should be heavily built. The relative merits of crushers are enumerated in text-books. Stamps are high in first cost and in working expenses, and produce much fines. For crushing purposes, steam stamps

are capable of a very large output. Ball-mills are compact, cheap, and economical to run; but they are small in output, and better adapted to prepare pulp than material for calcination. Chilian mills are rapid and effective; they are more suitable, however, for pulp-grinding than for reducing ore for the calciner or the smelter. Reciprocating crushers, such as the Blake, especially of the multiple-jaw type, are cheap; they do not make excessive dust; and they crush fine enough for roasting or smelting. Gyratory mills, such as the comet, have similar advantages, and being more continuous in action, are larger in output. Rolls work with economy, have a large output, and are suitable for crushing every variety of ore or matte to the size required for the calciner or the smelter. The Niagara pulverizer works well, but produces much dust.

Concentration forms the second step in the treatment of copper-ore. The higher the degree of concentration, that is, the more tons of ore that can be put into a ton of matte, the lighter per ton of the original ore will be the subsequent costs of refining this matte. This concentration is effected either wholly in the furnace; or partly in mechanical concentrators, with the aid of water, and partly in the smelter. The choice of method is almost entirely a question of economy. When the ore is mixed with gangue, consisting largely of quartz, slate, limestone, felspar, decomposed granite, etc.: that is, of materials having a much lower specific gravity than sulphide of copper, wet concentration is largely adopted. But, with the best appliances, and the greatest care, the loss in so concentrating copper-ores averages from 25 to 30 per cent. On the other hand, to fuse and run off as slag the entire mass of original rock, in the furnace, may, unless the gangue is self-fluxing, involve the use of additional fuel and labour, exceeding the value of wet-concentration losses. The question, therefore, resolves itself into one of relative cheapness, and can be solved only by actually concentrating a ton or more of the ore, and comparing the value of the mineral lost, with the extra cost of smelting the unconcentrated bulk. There are, however, cases in which the problem can be solved *a priori*.

When copper-ores carry even a very moderate amount of gold and silver, with sufficient copper to collect the precious metals into a rich matte, preliminary wet concentration is not desirable, since the loss in precious metals will usually exceed the cost of extra

fuel, etc. Thus, the Argo smelter smelts, without concentration, ores carrying some gold and silver, with about 3 per cent. of copper, and in a single fusion, concentrates 12 or more tons of ore into 1 ton of 40 per cent. copper matte. Ore with a higher copper percentage would in this case be less suitable, because, apart from other reasons, there would be heavy losses of gold, silver and copper in the slag, if a matte containing more than 50 to 60 per cent. of copper, were made; while, without doing so, the rate of concentration of the precious minerals, with a richer copper-ore, would be low. Thus the Argo, which, commercially, is a gold-and-silver smelter, does not use ores rich in copper, unless they are also very rich in the precious metals; but seeks to make a matte, rich in bullion, by concentrating a number of tons of low-grade ore. On the other hand, the Butte smelter finds it more rapid and profitable to wet-concentrate low-grade ores to 10 or 20 per cent. of copper, before smelting them. The difference of practice is in both cases guided by motives of economy.

2.—Calcination.

Roasting or calcining is, in most cases, the third step in the treatment of copper-ores. The chief object of calcination is the reduction of the sulphur-contents of the ore to the amount required to produce a matte of a certain grade. This amount varies with the quantity of arsenical or antimonical speiss, if any, to be formed, and with the furnace-coefficient of sulphur loss by oxidation, volatilization, and slagging. These losses, of which no accurate data appear to be available, vary widely according to the volume of the blast, the shape of the furnace, the temperature, the character of the slag, etc. A very usual loss in normal smelting (with fairly good running, a large volume of blast, and considerable lime and magnesia) is from 5 to 10 per cent. of the sulphur in the charge. Furnaces are occasionally run, with a sulphur oxidation of 16 to 21 per cent., and with a slag high in lime (melting, therefore, at a high temperature), nearly half the sulphur not appropriated by the copper will enter the slag, or pass off as gas. In rapid work, and when plenty of iron is present, with lead, zinc and manganese, it is reckoned that 75 per cent. of the lead, 50 per cent. of the zinc, and 25 per cent. of the manganese present may be considered as forming monosulphides, in the following proportions:—Every unit of lead needs 0·199 sulphur, every unit of

zinc requires 0·5 of sulphur, and every unit of manganese takes 0·6 of sulphur. An extra amount of sulphur, therefore, must be left in the charge when these minerals are present. Of the sulphur, in sulphates of baryta, lime, and soda, only 10 per cent. should be considered as available for combining with copper or iron.

To illustrate a method of calculating the amount of residual sulphur to be left in the calcines, to yield, in blast-furnace smelting, a matte of a given copper percentage, the writer has assumed a concrete case, and afterwards deduced a general formula. It is assumed, for example, that the matte is to contain 40 per cent. of copper. The contents of this matte, subsulphide of copper and ferrous sulphide, may be expressed in percentages thus:— (40 Cu + 10 S) + (31·85 Fe + 18·15 S). And the matte will require 28·15 per cent. of sulphur. In order to find what percentage of sulphur in the ore (say a 6 per cent. copper-ore), this amount of sulphur in the matte represents, it is necessary to determine how many tons of ore are required to form 1 ton of 40 per-cent. copper matte. This is given by the formula: $40 \div (6 - 0{\cdot}5$ loss$) = 7{\cdot}27$ tons. The residual sulphur in the charge of ore is, therefore, stated by the fraction $28{\cdot}15 \div 7{\cdot}27 = 3{\cdot}8$ per cent. In other words, the original contents of the ore should be reduced, by calcination or by an admixture of oxide-ore, down to 3·8 per cent. of sulphur, exclusive of the amount needed for speiss, and for making good the smelting losses.

The above results may be stated in a general formula, thus:— Let x be the percentage of copper in the matte to be formed; and y the percentage of copper in the ore to be calcined. Then the composition of the desired matte may be expressed in percentages as:—

$$\left(x + \frac{x}{4}\right)\mathrm{Cu_2S} + \left(100 - \frac{5x}{4}\right)\mathrm{FeS};$$

or more fully

$$(x\ \mathrm{Cu} + 0{\cdot}25x\mathrm{S}) + 0{\cdot}637\left(100 - \frac{5x}{4}\right)\mathrm{Fe} + 0{\cdot}363\left(100 - \frac{5x}{4}\right)\mathrm{S}.$$

In this, the sulphur percentage is 0·25 of x + 0·363 of $\left(100 - \frac{5x}{4}\right)$. Consequently, the percentage of sulphur to be carried by the charge, in order to yield a matte of x per cent. of copper is:—

$$\frac{\left[0{\cdot}25\ x + 0{\cdot}363\left(-100\frac{5x}{4}\right)\right](y - 0{\cdot}5\ \text{loss})}{x}.$$

To the percentage, so calculated, must be added (1) the sulphur required for speiss, if any; and (2) the sulphur, removed in the furnace by oxidation, volatilization, etc. It may be remarked that a charge with any given percentage of sulphur, if smelted in a reverberatory furnace, will yield a matte about 8 per cent. richer than if smelted in a blast-furnace.

3.—Methods of Calcining Copper-ores and Mattes.

Table I. shows the advantages and disadvantages of the several methods of roasting copper-ores and mattes.

4.—Chemistry of Copper-ore Calcination.

The chemical changes, produced in calcination, affect both ore and gangue. As regards the former, the first change is the partial oxidation of the sulphides, chiefly pyrites, by the burning or oxidizing of that atom of sulphur which is only feebly combined. This reaction is accompanied by a blue, flickering flame, and the emission of sulphurous acid gases and steam. The second change is the combustion of the second atom of sulphur. This reaction, which is more rapid and energetic, is attended by the emission of sulphuric, in addition to sulphurous acid gas. The products of this reaction are firstly, the formation of sesquioxides and protoxides of iron; and, then, as the temperature rises, the production of oxides of copper, sulphates of copper and silver, with oxides and sulphates of lead, zinc, etc. To assist in the elimination of antimony and arsenic, some 4 to 6 per cent. of charcoal-dust, fine bituminous or anthracite-coal screenings may be stirred up with the ore, the temperature being raised to the highest permissible limit so as to volatilize these impurities. The roast is continued, until the sulphur in the charge is reduced to the required percentage.

The calcination of copper-ore for reverberatory-furnace or for blast-furnace work is practically the same. But in roasting for reverberatory smelting, it is well to avoid an excess of air, towards the close of the roast. The object of this precaution is to prevent the oxidation of any large proportion of the iron to sesquioxide, which is infusible and unfit to enter the slag, until reduced to protoxide. In the powerful carbonic-oxide atmosphere of the blast-furnace, this reduction takes place instantly; but in the almost neutral atmosphere of the reverberatory furnace, the

TABLE I.—ADVANTAGES AND DISADVANTAGES OF SEVERAL METHODS OF ROASTING COPPER-ORES AND MATTES.

Method of Roasting.	Advantages.	Disadvantages.	Remarks.
Heap-roasting of ore.	It avoids the heavy initial outlay on calcining-plant. It yields a product excellently suited to the blast-furnace. It does not require much labour, nor, in the case of ores rich in sulphur, much fuel. It is adapted for the kernel-roasting of highly pyritic, non-crepitating ores.	It is a slow process, and, therefore, locks up capital. It does not admit of careful regulation; and, with many ores, gives imperfect results. It is not suitable for roasting fine ores in bulk, unless agglutinated. It requires large floor-space, and unless under shelter, wind and rain may cause losses. The sulphur cannot be utilized for making sulphuric acid; and at least 10 per cent. of the ore has to be re-roasted.	The use of heap-roasting is confined to localities where damage to vegetation is of no consequence; where there is no market for sulphuric acid; and where the cost of fuel and labour is high.
Heap-roasting of matte.	The condition of heap-roasted matte is very favourable for smelting.	In heap-roasting, the matte must undergo several calcinations, and the cost of these is usually more than crushing and calcining the matte in furnaces. On account of their easy fusibility, mattes containing 15 per cent. or more of lead are not suitable for heap-roasting. Other objections are the same as stated above.	The process is often employed as a finishing roast for mattes previously calcined in shaft-furnaces. Otherwise, heap-roasting is advisable only in outlying districts, when the cost of furnaces cannot be at once incurred.
Stall-roasting of ore.	It is 80 per cent. quicker than heap-roasting. It avoids losses by wind or rain. It is simple and easily managed; and, in the case of pyritic ores, requires little fuel. All the ore is roasted, and the process is suitable for kernel-roasting. Moreover, the noxious fumes can be concentrated in one flue, and discharged at a height that ensures their harmlessness by air-dilution.	Though quicker, it involves larger capital outlay and heavier working costs than heap-roasting. The sulphur in the gases is wasted; and the emptying of the stalls is unhealthy for the workmen.	Stall-roasting may be employed where fuel is dear, and there is no demand for sulphuric acid. Or, again, where kernel-roasting is desirable; or where partly roasted lump ore or mattes from shaft-furnaces have to be re-roasted.

TABLE I.—*Continued.*

Method of Roasting.	Advantages.	Disadvantages.	Remarks.
Heap-roasting of matte.	For this purpose, stall-roasting is about 33 per cent. quicker than heap-roasting; and shares the advantages enumerated above.	The process requires the matte to be roasted at least thrice; and it labours under the foregoing objections.	See preceding remarks.
Shaft-roasting of ore or matte.	Both lump and fine ore can be heated; little fuel is wanted; and the gases can be utilized for making sulphuric acid.	The costs of construction and of labour are high, and the output is small. The ore must contain enough sulphur to act as fuel, and must not readily fuse, sinter or decrepitate at the temperature of calcination. Mattes cannot be roasted sweet, but retain 10 to 14 per cent. of sulphur. Shaft-roasting is therefore only a preliminary to a subsequent roast in heaps or stalls for lump ore, and in reverberatories for crushed matte.	Shaft-furnace roasting is appropriate only where labour is cheap, fuel dear, and where there is a market for sulphuric acid.
Kiln-roasting.	The chief advantage is that the gases can be utilized in sulphuric acid manufacture.	The use of this method is limited. In order to have a sufficiently high percentage of sulphur, to act as fuel for the roast, and to avoid handling worthless material, the ore must be almost freed from gangue. The minimum percentage of sulphur needed to maintain combustion in kilns is about 25 per cent. Sulphides, other than bisulphide of iron, are objectionable. Lead increases the fusibility of the charge, besides wasting sulphur by forming stable lead sulphate. If the ore contains more than 8 per cent. of copper in the pyrites, it becomes too fusible and low in sulphur to be profitably used for making sulphuric acid. Arsenic and antimony greatly injure the quality of the resulting acid. The process requires much skill and labour.	Kiln-roasting is rather an operation in sulphuric acid making than a method of roasting copper-ores.

TABLE I.—*Continued.*

Method of Roasting.	Advantages.	Disadvantages.	Remarks.
Reverberatory-roasting by hand.	The reverberatory furnace is a rapid roaster, and can be regulated with precision. It is the best method for removing arsenic and antimony. It is applicable to all classes of ore, and is the most suitable method for roasting matte, as it allows a large quantity to be roasted sweet in the shortest time.	The ore or matte must be pulverized. The gases are too dilute to be used for sulphuric acid. The labour and fuel costs are high.	Reverberatory roasting commends itself when there is no market for sulphuric acid; or when the acid, because of the matte being too rich in copper or the gases being too poor in sulphur, cannot be profitably made. It is also very suitable as a finishing roaster for crushed matte.
Reverberatory-roasting: automatic	Large capacity; low labour costs; easy management.	Expensive in first cost; and, in some types, heavy in repairs.	Automatic calciners are particularly well suited to roasting pyritic gold-ores, concentrates, leady mattes, and material inclined to sinter.
Revolving cylinder-roasting.	Their gentle and regular heat gives them advantages in roasting easily fusible substances. They are also very well suited for effecting a thorough chloridizing roasting at a very moderate cost.	High in construction costs, and in fuel-consumption.	Suited for roasting mattes, containing much lead, also chloridizing silver-ores; but are not much used by copper-smelters.
Muffle-furnace-roasting.	Admit of very exact roasting, and of the use of the gases for sulphuric acid manufacture.	Costly in construction, fuel and labour. Suitable only for fine ore or crushed matte.	Are more an adjunct for sulphuric-acid making than copper-ore roasting. Can be used for ores unsuitable for the shaft-furnace on account either of their being too low in sulphur, or too fusible on account of the presence of lead, or too prone to crepitate.

sulphur alone plays the part of a reducing agent, and a charge of sesquioxide of iron materially delays fusion, besides producing thick, foul slag. In order to prevent this excess of oxygen, in the last stage of the roast, a small percentage of fine coal may be stirred into the ore and fired vigorously.

The changes effected in the gangue by calcination are simple: silica remains unchanged; calcspar becomes sulphate of lime; and sulphate of baryta, at very high temperatures, may be changed to soluble sulphide.

5.—Calcination Losses.

The copper-losses in careful roasting are small, and, being chiefly mechanical, are mostly recoverable when arrangements are made for collecting the flue-dust. The average loss is perhaps 1¼ per cent. of the original copper contents of the ore. The flue-dust, to which this loss is principally due, is usually much poorer in copper than the ore; moreover about 20 to 30 per cent. of its copper is in a soluble form, so that water, as an aid to the condensation and collection of the dust, should not be used, unless the copper, leached out, can be afterwards easily precipitated. Flue-dust, except for ores very free from impurities, should be smelted separately.

6.—Chemistry of Copper-smelting.

The object of copper-smelting is to fuse, separate, and collect the commercial metals into what is termed matte or regulus, while the worthless or injurious impurities are volatilized or slagged away. Although the results of smelting are the same, whether conducted in a reverberatory furnace or in a blast-furnace the reactions accompanying the formation of the matte and slag are different and may, therefore, be considered separately.

The blast-furnace admits of two extreme methods of work; it may be run with a highly reducing atmosphere, or with a highly oxidizing one. In the former case, the tendency would be for the bases to be reduced to metallic conditions, and to be separated out as metals, the product of this fusion being mainly metallic copper and metallic iron. Under the latter condition, the tendency would be for the bases to become oxidized, and to combine with the silica to form slag. Both these extremes have to be avoided, and a middle course adopted. In practice, however, it would be extremely difficult to maintain the happy medium and to avoid a loss of copper in the slag. The smelter, therefore, provides himself with a protecting agent which guards him against evil results, even when his method of running inclines too much to one or the other extreme. This agent is sulphur, and it is for this

reason that a certain percentage of sulphur is left in the roasted ore. Sulphur has a strong affinity for copper and for iron. So long, therefore, as there is sufficient sulphur in the charge, practically no copper can enter the slag. For, even if the furnace atmosphere were too oxidizing, and oxide of copper were formed, it would be at once decomposed by the sulphur, forming subsulphide of copper (Cu_2S), and sulphurous acid gas, which again is decomposed to sulphur by the carbonic oxide burning to carbonic acid. For practical reasons, it is not desirable to form a matte composed solely of sulphide of copper; and therefore additional sulphur is left in the charge in order, by combining with iron, to form as much sulphide of iron as is required to dilute the matte to the desired percentage of copper. It is evident, therefore, that the copper grade of the matte (Cu_2S, FeS) depends on the amount of sulphur present; for, after a certain proportion has been burned in reducing the oxide of copper to metal, and a still further amount (1 pound of sulphur to 4 pounds of copper) has been combined with copper to form subsulphide, every pound of sulphur left, and not oxidized or volatilized, will take up $1\frac{3}{4}$ pounds of iron, thus diluting the matte to the extent of $2\frac{3}{4}$ pounds of worthless sulphide of iron.

The specific reactions which, in the blast-furnace, take place between the oxides and sulphides of iron and copper (and, to a subordinate degree the sulphates) present in the roasted ore, are: — (1) Reduction of peroxide of iron to protoxide, and the combination of this with silica to form slag. (2) Decomposition of sulphide of iron by oxide of copper, in the presence of carbon and silica, forming sulphide of copper and silicate of iron. (3) Reduction of some oxide of copper to metal, by carbon and carbon monoxide. (4) Reduction of sulphate of copper to copper sulphide. (5) Reduction of oxide of zinc, in part, to metallic zinc, volatilization of the same, and combination of part of the zinc oxide with the slag. (6) Partial oxidation of sulphate of zinc to zinc oxide, and partial reduction to zinc sulphide. (7) Passage of some of the zinc sulphide into the matte, but of most into the slag. (8) Reduction of lead from its oxide and sulphate to metal or to sulphide, and its passage into the matte. (9) Reduction of antimoniates and arseniates partly to antimonides or arsenides, and partly to metals, with volatilization of the same; in the presence of iron-pyrites, a little of the antimonides and arsenides enters

the matte, while part of them may form speiss. (10) Reduction of barytes and gypsum to sulphides. Sulphides of barium may enter the matte. In the presence of silica and sulphide of iron or metallic iron, a readily fusible double silicate of baryta and iron is formed. (11) Inclusion of silver and gold in the matte. (12) Slagging of quartz, silicates, earths, etc.

In the reverberatory furnace, the reactions which (chiefly owing to sulphur and incandescent carbon) take place among the charge-constituents, and are very similar to those in the blast-furnace charge, are:—(1) Conversion of oxides and sulphates of copper, in the presence of sulphur, into sulphides, which together with the sulphides of copper and iron, in the charge, form matte (coarse metal). (2) Reduction of ferric oxide, in the presence of sulphur, to ferrous oxide, which combines with silica to form slag. (3) Passage of oxide of zinc into the slag, and of sulphide of zinc, partly into the slag and partly into the matte. (4) Sulphide of lead, together with the gold and silver, enters the matte. (5) Arseniates and antimoniates act as in the blast-furnace. (6) Alkalies and alkaline earths combine directly with silica to form slag.

A noteworthy difference in the respective actions of the blast-furnace and of the reverberatory furnace lies in the greater richness of the matte produced in the latter. In the strongly reducing atmosphere of the blast-furnace, but little sulphur can be directly oxidized, consequently it simply fuses with the copper and iron present and forms matte. The sulphurous acid gas, that is formed in the blast-furnace, comes in contact with an overwhelming proportion of carbonic oxide, which, in burning to carbonic acid, robs the sulphurous acid of its oxygen, reducing it to sulphur, which unites with the copper and iron. In the reverberatory furnace, on the other hand, the reducing agent, carbonic oxide, is practically absent, and the furnace-atmosphere is neutral. Consequently much of the sulphur escapes as sulphurous acid gas, and leaves less sulphur to combine with the copper and iron. Of this residual sulphur, the copper seizes all that it requires to form subsulphide, consequently less remains for the iron, and the quantity of ferrous sulphide formed being less, the matte is richer in copper.

The same charge, therefore, if smelted in a reverberatory furnace will produce a richer copper matte than if treated in a blast-

furnace. This difference in richness is found to be about 8 per cent. in favour of the reverberatory furnace. Hence, also, if it is expedient to have a small calcining-plant, it is, other things being equal, better to smelt in a reverberatory furnace, since a large amount of sulphur can be removed.

7.—Methods of Copper-smelting.*

The various methods of copper-smelting are known as:—(1) The German or blast-furnace; (2) the English or reverberatory furnace; (3) the Welsh; (4) the Anglo-German or mixed; (5) the pyritic; (6) the converter or Bessemer process; and (7) special processes.

I.—German or Blast-furnace Process.

The blast-furnace process involves the use of carbonized fuel (coke or charcoal) which acts both as fuel and reducing agent. The process is rapid, and adapted practically to all classes of ores:—oxides, sulphides, or metal. With proper constitution of the charge and management of the furnace, the slags should be poor enough to throw away. Owing to the reducing action of the carbon on the impurities present, the matte is less pure than that obtained in the reverberatory furnace, and as previously explained, lower in its percentage of copper. The blast-furnace may be advantageously used where carbonized fuel is cheap, and the ores are of uniform composition; with low-grade ores, and with those associated with notable quantities of arsenic, antimony, lead; also with highly ferriferous ores, that would too strongly attack the hearth of a reverberatory furnace.

The German process, in its simplest form, comprises three operations:—

(*a*) *Calcination of the Ore.*—In some cases, where sulphide-ores are intermixed with large quantities of earthy gangue; or where ores are rich in copper, but poor in sulphur, calcination of the ore is omitted, or employed only to remove bituminous matter, if present.

(*b*) *Smelting to Matte.*—When the ore is poor in copper, but rich in iron-pyrites, or carries arsenic, antimony, lead, etc., the matte produced by this smelting will be so impure as to need re-treatment.

* This subject is fully treated in the *Handbook of Metallurgy* by Messrs. Schnabel & Louis.

(*c*) *Re-treatment of Impure Mattes.*—Impure mattes are roasted sufficiently to leave just enough sulphur to form a second, purer, and richer matte, known as 'fine metal.' If this second matte is still too impure and poor, it is again re-treated; and, occasionally, as for instance when the matte contains much lead, the re-treatment may have to be repeated a third time before 'fine metal' is obtained. This product is then roasted sweet and smelted to 'coarse copper.' To slag off the iron in the fine metal, acid slags from the ore-furnace, quartzose copper-ores, or ores mixed with acid silicates are added, in such proportion that a monosilicate-slag is formed. This slag always contains at least ½ per cent. of copper and is added to the ore-furnace charge. These re-treatment operations, which are termed 'concentrating' or 'doubling,' are usually conducted in reverberatory furnaces, because purer mattes are thereby obtained. But mattes, rich in lead, and yielding lead on smelting, are better roasted in shaft-furnaces. This is also the case with plumbiferous copper-ores. Thus, the Oker ores, containing 4·78 per cent. of copper, 8·84 per cent. of lead, 12·55 per cent. of iron, and 24·11 per cent. of sulphur are first calcined in shaft-furnaces to 10 or 12 per cent. of sulphur, then further desulphurized, by two heap-roastings, to 5 or 6 per cent. of sulphur, and afterwards smelted in the blast-furnace, producing work-lead, and matte with 16 to 20 per cent. of copper; 4 to 5 per cent. of lead, and 0·02 per cent. of silver. This matte is roasted in shaft-furnaces, and smelted in a blast-furnace, with siliceous copper-ore, yielding matte with 45 per cent of copper, and 0·05 to 0·06 per cent. of silver, also an alloy of copper, lead, arsenic and antimony, containing up to 60 per cent of copper.

But, as just stated, matte re-treatment and its ultimate smelting to 'coarse' or 'black copper' are generally done in reverberatory furnaces, so that the German process is seldom employed in its entirety, but usually encroaches on the English, and becomes Anglo-German.

II.—English or Reverberatory-furnace Process.

This process requires flaming, but as far as possible, smokeless fuel, such as coal, lignite, peat, wood, gas, oil, etc. The fuel is needed merely to produce the heat necessary for the progress of the reactions, the most important of which are those of the sulphides of iron and of copper on the oxides of copper. For this reason, the

English process is primarily adapted to the treatment of sulphide-ores; and only in a subordinate degree to that of oxides and metal. The matte produced is purer, because arsenic, antimony and tin can be collected in a certain amount of 'coarse copper,' called 'bottoms.' But the slags are not so clean, and require re-treatment. The English process, therefore, is suitable where raw fuels are cheap; where the ores are of varying composition, or are sufficiently rich for the loss of copper in the slag to be proportionally less important; or in the case of rich but impure ores, containing considerable arsenic and antimony; or where the ores are siliceous or clayey, and do not attack the furnace-hearth too strongly; and lastly, when it is desired to produce pure grades of copper.

The English reverberatory-furnace process comprises the following operations.

(*a*) *Calcining the Ore.*—For this purpose, long reverberatory furnaces with hand or machine-rabbling are much in use. Rotating cylinders of the Brückner and Oxland types are also in use, as well as shaft-furnaces, where sulphuric acid making is intended. For this latter purpose, if the ore is too fusible to be calcined in a shaft-furnace, a Hasenclever furnace is one of the best substitutes.

TABLE II.—SHOWING HOW THE COPPER IN THE SLAG VARIES WITH THE MATTE.

Copper in the Matte. Per cent.	Copper in the Slag. Per cent.
64·3	0·85
62·7	1·05
66·5	0·92
66·2	1·10
65·9	0·67
61·8	0·64
63·3	0·87
64·5	0·82
63·3	0·76
66·2	1·32

(*b*) *Smelting to Matte, that is, 'Coarse Metal.'*—In smelting the calcined ore in a reverberatory furnace, the slag should be intermediate between monosilicate and bisilicate. The various ores should be so mixed that the amount of slag does not exceed 30 per cent. of the weight of the ore. Too large a quantity of slag would cause heavy copper losses. If it is required to leave less than ½ per cent. of copper in the slag, the charge must not contain over 35 per cent. of copper. Where ores are rich and pure, but

labour and fuel are dear, it may be more economical to calcine more thoroughly so as to produce a 60 per cent. copper matte, and leave over 1 per cent. of copper in the slag. Dr. E. D. Peters, junior, has compiled Table II., showing how the copper left in the slag varies with the richness of the matte.

The English process can be extended to the re-treatment of the matte, 'coarse metal,' with 30 to 35 per cent. of copper. The operations for this purpose are as follows:

(*a'*) *Calcination of the Matte.*—The degree of calcination or desulphurization depends on whether the next smelting is to produce a concentrated matte, 'white or fine metal,' or 'coarse copper.' If the former, the coarse metal or matte is calcined sufficiently to produce a 60 to 75 per-cent. copper matte. If the latter, the coarse metal is calcined sufficiently to yield on smelting 43 to 48 per cent. of coarse or black copper, containing 92 to 95 per cent. of copper and 2 to 3 per cent. of concentrated matte. Occasionally, in the case of very pure and rich ore, the first matte or coarse metal is smelted direct to 'blister or coarse copper.'

(*b'*) *Smelting the Matte.*—The smelting of the matte, coarse metal, to white or fine metal, or direct to blister or coarse copper, is done in the reverberatory furnace, quartzose ores or quartz being added to slag off the iron. By adding, to the charge, oxidized ores, such as carbonates of copper, cuprite, or slags rich in copper, it is possible to produce rich matte, fine metal from poor coarse metal with only about 30 per cent. of copper.

(*c'*) *Smelting White or Fine Metal to Coarse Copper.*—This may be done in two ways:—

(1) By first calcining the white metal to 4 or 5 per cent. of sulphur, and then smelting it with a little refinery slag or raw, that is, uncalcined white metal.

(2) By repeated oxidation and reduction of the raw white metal in a reverberatory furnace, the slag being skimmed off, after each reduction, the temperature lowered, and an excess of air admitted. This method is known as 'roasting,' and is peculiar to the Welsh process. The white metal is first slowly heated, with free access of air, until it softens, and is left for some time in this state. It is then smelted down very slowly, drop by drop, during which process the sulphides are partly converted into oxides, these reacting upon the sulphides with evolution of sulphur dioxide from the molten mass. When this ceases, the slag is skimmed, the tempera-

ture lowered, more air admitted, and the operation repeated. On an average, white metal yields 60 per cent. of coarse copper, and 8·7 per cent. of rich slag, called 'roaster slag.' The coarse copper, full of cavities, is known as blister copper, and contains from 97 to 98·7 per cent. of copper.

III.—Welsh Process.

A rather more complicated application of the English is the Welsh process, which is applied to the treatment of coarse metal, and, according to the object in view, consists of the following operations:—

(1)—(*a*) Calcining the coarse metal or matte; (*b*) smelting the calcines to white metal; and (*c*) roasting the white metal to coarse or blister copper. When copper of ordinary quality is wanted, the coarse metal is smelted with sufficient oxidized material to produce white metal with about 75 per cent. of copper. If better or tough copper is required, the amount of oxidized ore is increased so as to produce a certain proportion of bottoms.

(2)—(*a*) Calcining the coarse metal; (*b*) smelting the calcines to pimple metal; and (*c*) roasting the pimple metal to coarse or blister copper. These steps are used when it is desired to obtain blister copper from pure coarse metal in a relatively short time. This is done by adding more oxidized material to the calcined coarse metal.

(3)—(*a*) Calcining the coarse metal; (*b*) smelting the calcines to blue metal; (*c*) roasting the blue metal to special white metal; and (*d*) roasting the special white to blister copper. These operations are performed when high-grade or best selected copper is to be made. The blue metal is made by using coarse metal, either slightly calcined or else smelted with small quantities of oxidized material. At some works, the coarse metal is not calcined, but roasted direct to blue metal. The special white metal contains about 77 per cent. of copper. The roasting of special white metal to blister copper is conducted in the ordinary way.

(4)—(*a*) Calcining the coarse metal; (*b*) smelting the calcines for blue metal; (*c*) roasting the blue metal to special white metal; (*d*) roasting the special white metal to fine metal; and (*e*) roasting the fine metal to blister copper. This method is employed to obtain the better grades of copper. The special white metal is roasted with one-fifth by weight, of red or white slag-metal,

obtained by smelting slags with copper-pyrites. In consequence of the large amount of cuprous oxide in the slags, 100 parts of charge yield 10 per cent. of bottoms, with 92 to 93 per cent. of copper; the rest of the product being 64 per cent. of fine metal, with 81 per cent. of copper; and 11 to 12 per cent. of slag, with 11 per cent. of copper.

(5)—(*a*) Smelting cupriferous slags for red and white slag-metal; (*b*) roasting red and white slag-metal together with special white metal to fine metal; and (*c*) roasting fine metal to blister copper. The red and white slag-metals are obtained by smelting the slags, produced in the various smelting operations for white metal, special white metal, and fine metal, with quartzose copper-pyrites and a little culm. The products are the mattes, known as red and white slag-metal and bottoms. With ores and mattes, containing tin, what is known as hard metal is formed as a layer, above the bottoms.

(6)—Treatment of copper bottoms. (*a*) When the bottoms do not contain precious metals, they are either added, in certain proportions to mattes, when roasted for blister copper; or they are roasted by themselves to blister copper. (*b*) When the bottoms contain precious metals these are extracted by dry or wet or electrolytic methods.

(7)—Treatment of blister copper. This is refined, and forms the lower grades of copper, known as cake copper, when in the form of bars; or as tile copper, when in the form of slabs.

IV.—Anglo-German Process.

In this mixed process, blast-furnaces are used for smelting, because they are cheaper to run and produce cleaner slags; in good work, sufficiently clean to be thrown away. But the matte is concentrated in reverberatory furnaces, which produce the purer mattes, such as are needed for making pure copper, and for many methods of extracting their silver-contents. It is also easier to collect, in the bottoms, any gold present.

The smelting to coarse copper is done either in a blast-furnace or in a reverberatory furnace.

V.—Pyritic Process.

Pyritic smelting of copper-ores has already been discussed at some length by the writer, in *Engineering*.* With a hot blast, the

* June 15th, 1900, vol. lxix., page 774.

coke-consumption has been reduced to 1·5 per cent. of the weight of the ore. Matte is excellently suited for this process, and can be readily concentrated from 30 up to 50 or 60 per cent. of copper in a blast-furnace, without the use of any fuel, except that consumed for heating the blast.

VI.—Converter or Bessemer Process.

This process is used for obtaining coarse copper from mattes produced by the German, English, or Anglo-German methods. The principle is to force air through the molten matte, thereby converting the sulphides of copper and iron into cuprous and ferrous oxides, with the evolution of sulphur dioxide. The cuprous oxide decomposes any undecomposed sulphide of copper, producing metallic copper and sulphur dioxide, while the ferrous oxide is slagged off by the silica of the converter-lining. If the blast is continued long enough, coarse copper and slag are obtained; if it is stopped earlier, a richer matte and slag result.

Raw ore or very low-grade mattes are not suitable for this process, partly because more slag would be formed than could be conveniently handled, or kept fluid by the heat developed by the oxidation of the sulphides; partly because the excess of iron in such mattes would too strongly attack the converter-lining; and partly because no practical system of continuously feeding in the matte has been found. The mattes, therefore, to be suitable, should contain at least 25, and preferably 45 to 50 per cent. of copper. Mattes containing more than 60 per cent. of copper do not furnish enough heat by oxidation to complete the process.*

In bessemerizing poor matte, the charge is blown up to 60 or 70 per cent. of copper. The slag is then removed, fresh matte added, and the whole blown to 99 per cent. of copper. The work of the converter is known to be complete when the evolution of sulphur dioxide ceases, and little particles of copper appear in the flame. In the process, arsenic and antimony are completely volatilized; zinc is partly so, and partly slagged off; lead, tin and cobalt pass into the slag; and nickel and bismuth remain in the copper. Converter-slag is sufficiently rich to need re-treatment, and on account of its iron is a useful flux for melting siliceous ores.

* The heat-units freed by oxidation are: for sulphur, about 2,200; and for iron, about 1,576. To these should be added the heat from the combination of iron and silica, while a considerable reduction must be made for the dissociation of the sulphides.

The loss in bessemerizing, with provision for ample dust-chamber capacity, and not too many volatile metals in the matte, is from 1 to 1·5 per cent. of the copper. The loss in silver lies between 2 and 2·5 per cent. This latter loss increases greatly with the presence of volatile metals. Thus in bessemerizing concentrated matte from lead-silver furnaces, carrying 40 per cent. of copper and 15 per cent. of lead, the loss in silver has reached about 50 per cent. The loss also stands in close relation to the blast-pressure.

The heaviest expenses in bessemerizing are power for the blast, and refractory materials for the converter-linings. Hence with ample water-power, and the necessary quartz and clay, it may, where fuel is costly, be cheaper to produce a low-grade matte and throw more work on the converter. On the other hand, with cheaper fuel, and no water-power, it is generally better, especially with fine ores and concentrates, to do most of the desulphurization in the calciners and furnace.

VII.—Special Processes.

(1) Oxidized and acid copper-ores, poor in copper, are either added to the furnace-charge, in smelting sulphide-ores or mattes; or are treated by wet methods.

(2) Richer oxidized and acid copper-ores are either smelted alone in the blast-furnace, with flux and slag for matte and coarse copper; or are smelted with sulphide-ores or mattes by the English process, carbon being mixed with the ores, as a reducing agent.

(3) Ores containing native copper only require their gangue to be slagged off. This is best done in the reverberatory furnace, and should be immediately followed by refining. The slags are re-smelted for coarse copper in the blast-furnace.

8.—Refining of Coarse Copper by Dry Methods.

The chief dry method of purifying or refining coarse copper that does not contain precious metals, is by an oxidizing fusion, whereby the impurities are either volatilized or slagged off.

This fusion is now usually performed, in the reverberatory furnace, by the English process, and consists of an oxidizing fusion, immediately followed by the reduction of the cuprous oxide formed. As cuprous oxide, which possesses the property of fusing with copper to a homogeneous mass, diminishes the soft-

ness and tenacity of copper, both operations are repeated, until copper of the desired softness, toughness and density is obtained.

In many Russian works, a blast is used, especially in dealing with very impure coarse copper. As the refined copper cannot be tapped out, on account of its irregular flow and tendency to set in the tap-hole, it is run towards a depression and ladling-door, near the flue-bridge end, and it is thence ladled out, and cast into moulds. The best fuel is gas, wood, or coal burning with a smokeless flame, as any sulphur in the gases evolved affects the metal injuriously. In general, grates are preferable to gas-firing, because of the difficulty of introducing into the furnace sufficient air for oxidation.

As it is difficult to keep large quantities of copper at the proper pitch, during the slow process of ladling, the reverberatory furnaces are limited in size. Medium furnaces take 3 to 7 tons; large ones, 8 to 10 tons; and the largest, 12 to 15 tons.

The operations of refining depend on the composition of the coarse copper. If sulphur, arsenic and antimony are not present, it is merely a question of slagging off the gangue and iron. Where these impurities are present, the stages of the refining process are:—(1) Fusion, without or with partial air-admission; (2) scorification, with free air-admission, or with an air-blast; (3) boiling: cuprous oxide decomposing sulphide of copper, with production of metallic copper and sulphur dioxide; (4) dense-poling, to remove sulphur dioxide; and (5) tough-poling, to complete the reduction of cuprous oxide, and, consequently, the softening and toughening of the copper: during this step, the charge is usually covered with clean selected charcoal or anthracite.

As in the reduction of cuprous oxide by poling, the wood evolves gases that may result in the production of porous copper, re-agents that do not evolve gases, such as phosphorus or manganese (preferably in the form of phosphor-bronze or manganese-bronze) are sometimes used. Porous copper is suitable for brass-making, but not for rolling or hammering. For these purposes, porous copper may be rendered dense, by the addition of a little lead.

The products of a refining-furnace are tough-pitch copper or tough cake, and refinery-dross or slag. The consumption of fuel in refining varies from 33 to 63 per cent. of the weight of the charge, according to the quality of the fuel, the purity of the copper, and the size of the charge.

There is another method of refining, known as the direct method. Cuprous sulphide and cuprous or cupric oxide, in certain proportions, are fused together, yielding metallic copper and sulphurous acid gas. Details of this system, especially suited for treating impure metal or matte, as also argentiferous matte, and showing considerable economy over the English process, are given in Dr. Peter's *Modern Copper-smelting*. This authority suggests that, in order to avoid excessive silver-loss in argentiferous matte, it might be economical to bessemerize matte up to clean white metal containing say 78 per cent. of copper, using trough-converters and about 5 pounds of blast-pressure, and treating this white metal by the direct process, but so modifying the same as to avoid tough-poling and ladling, the copper being tapped into anode plates of the highest quality.

9.—Slags for Copper-smelting.

The choice of slags is chiefly a commercial problem. The locality or the conditions of transport may make it cheaper to work with a heavy loss in copper and silver, than to reduce these by using a metallurgically proper slag. In his work on *Modern Copper-smelting*, Dr. E. D. Peters, junior, states that "the usual object of smelting a copper-ore is simply to divide it into two portions: a small quantity of matte for further treatment, and a large amount of slag to go over the dump. Now it is entirely immaterial how this object is accomplished, or whether the ore has been thoroughly fused or only half melted, providing that the work has been done in the cheapest, quickest, and most effective way possible under the circumstances. For instance, the Swansea smelters long ago found out that it did not pay them to flux all the silica, when running on a highly quartzose charge. A reverberatory-furnace slag may contain close on 50 per cent. of unmelted fragments of pure quartz, and yet be clean and satisfactory; the main requirement being that there shall be a sufficient proportion of molten slag to float the unfused particles, and enable the worthless portion of the charge to be dragged out of the furnace, without carrying with it the valuable part. This species of liquation may at times be used to great advantage."*

When, however, the conditions are normal, and a free choice

* Page 234.

of slags can be made, their composition should be suitable to the ore. The main principles of suitability are indicated in Table III.

TABLE III.—NATURE OF SLAGS.

Nature of Slag.	Ores for which it is suitable.
Normal slags, intermediate between monosilicates and bisilicates, with ferrous oxide as the principal base.	Such slags are suitable for pyritic copper-ores, consisting chiefly, after calcination, of oxide of iron. They are also well adapted to zinciferous ores, because basic ferriferous slags dissolve considerable quantities of oxide and sulphide of zinc.
Bisilicate-slags.	These are specially suited for ores high in silica, because large quantities of bases would have to be added to form a slag low in silica, (60 parts of bisilicate require 144 parts of oxide of iron to form a monosilicate-slag, but only 72 parts of oxide of iron to form a bisilicate-slag). Unless, therefore, the iron-ore carried precious metals, the use of a monosilicate-slag would involve the smelting of a large quantity of barren flux.
Mixtures of bisilicate and trisilicate-slags.	Such slags are only used exceptionally, as in the case of the Mansfeld kupferschiefer, which contain the materials required to form such a slag, and are so low in copper (2 to 3 per cent.), that it would not pay to add barren flux.

It is evident, therefore, that in copper-smelting, there is great freedom as to slag-composition, provided always that the slag is kept sufficiently fusible, and sufficiently light, so as not to impede the separation of the matte. This separation of the matte from the slag depends mainly upon their difference in specific weight. Hence, it is difficult to keep the copper-loss low, when heavy, basic, ferruginous slags are used; on the other hand, the lighter, earthy or siliceous slags are usually free from grains of matte.

Table IV. shows the composition of slags used by several well-known smelters.

In view of the latitude in slag-forming there is little to be said in detail concerning the slag constituents. Except in very unusual cases as that of Mansfeld, the percentage of silica in the slag should not exceed 42 per cent.; even when it exceeds 36 per cent. the working of the blast-furnace is impeded. The effect of a high percentage of silica is to make the slag less fusible, to require, therefore, more fuel to produce the necessary higher temperature, at which, on the other hand, a certain proportion of

iron may be reduced and may be deposited, either as a wall accretion, or as a bear on the hearth-bottom, leading perhaps to chilling. For these reasons, very siliceous ores, low in copper, should be treated, either by reverberatory-furnace smelting, or, if that is not possible, by wet extraction. The best smelting results are attained with slags containing from 24 to 36 per cent. of silica; the lowest admissible percentage is 18 per cent. Slags, very low in silica, attack the furnace-lining and brickwork. A high percentage of iron, by increasing the specific gravity of the slag, impedes separation. It is also liable to form bears in the furnace. Even comparatively small quantities of magnesia, as also of alumina, greatly decrease the fusibility of the slag.* Such oxide of zinc as does not enter the slag is reduced and volatilized, and, being again reduced, is liable to be deposited as wall-accretions (furnace-calamine). Zinc sulphide, in large quantities, is likely to form, with the slag and matte, a porous mass, from which the copper is very difficult to extract. Zinc, therefore, should be eliminated, as far as possible, by roasting, etc., before the ore is smelted.

TABLE IV.—COMPOSITION OF SLAGS.

Where used.	Oker.	Oker.	Röros.	Oltenau	Fahlen.	Mansfeld.	Mansfeld.	Mansfeld.
Kind of slag.	Sub-silicate	Mixture of subsilicate and monosilicate.	Monosilicate.	Between monosilicate and bisilicate.	Between monosilicate and bisilicate.	Bisilicate.	Between bisilicate and trisilicate.	Between bisilicate and trisilicate.
Silica ...	21·62	25·24	31·44	34·67	40·28	48	54·13	57·43
Alumina	5·15	14·00	7·86	4·38	12·20	15	10·53	7·83
Lime	2·57	4·86	—	3·53	—	20	19·41	23·40
Magnesia	—	—	4·46	—	2·67	5	1·79	0·87
Ferrous oxide ..	65·62	45·96	55·21	48·25	49·80	5	10·83	7·47
Oxide of zinc ...	—	6·40	—	2·89	—	—	—	—
Cuprous oxide ...	2·26	Cu 0·35 to 0·55	—	—	—	—	2·03	0·30
Manganous oxide ...	—	—	—	2·00	—	—	—	—
Oxide of lead ...	—	—	—	1·07	—	—	—	—
Sulphur ...	2·08	—	—	—	—	—	—	—

In good work, under normal conditions, slags should not contain more than ½ per cent. of copper.

* Details of their action are described in *A Treatise of Lead-Smelting*, 1900, by the author.

10.—Blast-furnaces for Copper-smelting.

Blast-furnaces for copper-smelting may be divided thus: According to their purpose:—(1) Furnaces for reduction, and (2) furnaces for partial oxidation, succeeded by reduction. According to their form:—(3) Circular furnaces, and (4) rectangular or oval furnaces. According to their structure:—(5) Water-jacketted furnaces, and (6) brick furnaces. According to the settling arrangement:—(7) Furnaces with forehearths, and (8) furnaces without forehearths.

(1) *Reduction or Fusion-furnaces.*—These are used simply for smelting down ores, etc., not requiring a preliminary desulphurization. The changes, effected in such a furnace, are the elimination of the volatile constituents, and the combination of the sulphur with the copper and iron present, to form matte; also the union of the silica with such bases as are already oxidized by previous calcination or otherwise. If all the conditions are suitable, this simple smelting, in the powerfully reduced atmosphere of the furnace, produces the desired result, namely, the formation of a small quantity of rich matte, and the elimination of the gangue in a fusible, clean slag. But the very thorough calcination needed to prepare the ore for this form of smelting is costly, and not always possible; the more so, since many ores contain too little sulphur to warrant a previous calcination, and yet too much to produce a sufficiently rich matte, if reduced, without preliminary oxidation in the furnace. A very small proportion, therefore, of copper blast-furnaces fall under this class. Reduction-furnaces, however, are in place: (1) for remelting matte or rich ores for the converter; (2) for smelting ores consisting mainly of silica and bases, in an oxidized condition, from roasting or otherwise; and (3) lastly for smelting raw, low-grade copper-silver-gold ores, to a low-grade matte which is then blown up, in a converter, to a point at which the slag becomes rich enough to remelt. The object in such a case is to curtail or avoid the crushing, concentrating and roasting expenses and losses. The bessemerizing of such low-grade matte as 20 per cent. of copper, postulates improvements in the capability of converter-linings, and in the methods of removing slag from the converter, and continuously introducing fresh matte; it also demands cheap power for the blast.

Reduction or simple-fusion furnaces are characterized by: (1) contraction towards the bosh or tuyère-zone; (2) high ore-

column; (3) strong blast-pressure, for rapid smelting; (4) small or moderately-sized tuyères; and (5), probably as a useful adjunct, hot blast.

(2) *Partial Oxidation and Reduction-furnaces.*—In the generality of cases, it is advantageous to use the blast-furnace as a partial oxidizer, and thus produce a richer matte than would result, if the charge were simply melted down. This is effected by substituting a partial oxidizing atmosphere for a purely reducing one. While, therefore, in the reduction-furnaces, the shaft is contracted at the tuyère-zone, and a powerful blast is directed into a thus concentrated mass of coke and ore, producing thereby a high local temperature, and a dense atmosphere of carbonic oxide; in the oxidizing and reducing furnace, the opposite conditions prevail: the shaft-walls are kept perpendicular to avoid a contracted bosh, the heat being thus diffused over a wider area; and the pressure of the blast is reduced. Again, as a light blast cannot penetrate far into a charge, the furnace is made of narrow width, the capacity being maintained by increasing its length, thus determining a narrow rectangle as the most suitable form for such a furnace. Moreover, the blast being light, the supply of oxygen is maintained by enlarging, to 4 or 6 inches, the diameter of the tuyères, and thus increasing the volume of the blast. The ore-column also is made no higher than suffices to utilize the heated gases for partially roasting and oxidizing the ore in its descent. Lastly, as hot blast leads to local concentration of heat and too rapid fusion, a cold blast is preferred. In the reduction or fusion-furnace the ore, on reaching the fusion-zone, is almost instantly melted, and, dropping into the neutral hearth below, escapes all chemical influences; in the partially oxidizing furnace, on the other hand, the fusion is more gradual, and more time is given to oxidation and chemical reaction, before the ore reaches the hearth.

(3) *Circular Furnaces.*—The diameter of a circular furnace is limited by the distance to which the blast-pressure used can penetrate. With ores poor in iron, the pressure may be moderately high, and the furnace-diameter correspondingly increased. But with ores rich in iron, a high pressure is likely to reduce the iron; a lower pressure, therefore, has to be used, and the diameter proportionately reduced. Hence for such ores, a circular-furnace output is closely limited. Again, with charges that fuse with difficulty, the diameter at the tuyère-zone must be reduced for fear of

imperfect fusion at the centre of the charge. Table V. gives some particulars of circular furnaces:—diameter, height, blast-pressure, fuel consumption, etc.

TABLE V.—CIRCULAR BLAST-FURNACES.

Locality.	Nature of charge.	Blast-pressure.	Diameter at tuyère level	Height above bottom.	Fuel-consumption to charge
		Inches of mercury.	Inches.	Feet.	Per cent.
Oker (Lower Harz)	Easily fusible	1·4	51	19¾	20
Mansfeld	Kupferschiefer, hard to fuse	2·9 to 4·3	63 to 74	24 to 29½	16
Brixlegg (Tyrol)	Quartzose copper-ore	0·8 to 0·9	48	23	35
United States	Pyritic ore and sand	1·25	48	11	20

(4) *Rectangular Furnaces.*—Rectangular furnaces are better for large outputs, since the shorter side or width can be fixed to suit the blast-pressure and the nature of the charge; while the longer side or length can be increased to give the required output. In the 90 tons per 24 hours Orford furnace, the length is 11 feet 6 inches and the width 3 feet 6 inches. The walls of the Orford furnace are perpendicular, while those of the Raschette furnace widen out towards the top. Improvements have been made by rounding off the corners, making the section more that of an ellipse, as in the Skinder furnace used in the Urals, and the Herreshoff in the United States of America. The tuyères, from 3 to 14 in number, are distributed symmetrically round the periphery. The Heinrich is a water-jacketted furnace of rectangular cross-section, used in the United States of America.

(5) *Water-jacketted Furnaces.*—The advantages of water-jacketted furnaces are: Ease in erecting; simplicity in blowing in; facility and cheapness of repairs, costing usually less than half those with brick furnaces; convenience of manipulation; and the readiness with which wall-accretions can be removed. The disadvantages are:—In certain localities, the scarcity and impurity of the water, but this can usually be remedied; danger of ruining the furnace, by careless management of the feed-water; and waste of fuel by heat lost in the cooling water: this ranges from 2½ to 10 per cent. of the total fuel used.*

* If more than 6 per cent. is lost, either too much coke is being used or too much is being charged near the furnace-walls, or the water-circulation is too rapid and the water escapes at too low a temperature.

For copper-smelting, the jackets are usually made of wrought iron, soft steel, or rolled copper, for the inner shell, this latter material resisting corrosion by ore and gas containing sulphate of copper and sulphuric acid. The amount of water required is from 150 to 120 gallons per hour for furnaces with an area of from 3 to 8 square feet; and from 100 to 70 gallons for those with areas from 9 to 36 square feet. If the same water is used over and over again, from 15 to 25 per cent. must be added.

(6) *Brick Furnaces.*—The best representative of this class is the brick Raschette furnace, originally introduced by the Orford Copper Company and commonly known as the Orford furnace. Even these furnaces are now cooled in the region of the tuyères by water circulating in pipes embedded in the brickwork.

(7) *Furnace with Forehearths.*—The forehearths are either (*a*) outside and removable, or (*b*) outside but attached as continuations to the furnace. The great advantages of forehearths is that they allow the molten products to escape from the hearth, as soon as possible, and thus transfer the settling operation from the inside to the outside of the furnace. Thus burning out of the crucible, the formations of sows and accretions, etc., inside the furnace are avoided, and all troubles of this kind that occur in the forehearth can be seen and remedied without the expense of blowing out.

(*a*) Furnaces with independent forehearths. These forehearths which are vessels, into which the molten products flow and separate, according to their specific gravities, are open or covered, independently heated or otherwise. They are advantageously used in smelting highly ferriferous ores, such as calcined pyrites, where there is danger of iron sows forming on the bottom, if the molten material is allowed to remain too long in the furnace. For the steady smelting of uniform copper-ores, producing a moderately free slag, and a matte containing between 20 and 50 per cent. of copper, the Herreshoff water-jacketted type is suitable. But it is not adapted to inexperienced labour, irregular running, frequent stoppages, sudden changes in ore, or very siliceous slag. Given favourable conditions, however, it produces a matte free from slag and other impurities. Independently heated forehearths are practically small reverberatory furnaces. The furnace discharges its molten products into the hearth of the reverberatory furnace, through an opening in the rear wall of the latter, and the clean

slag flows off continuously at the front or skimming-door end. The separation of the matte and slag is facilitated by the heating of the forehearth. The hearth is best formed of ordinary Stourbridge brick. This is, perhaps, the best and most economical forehearth that can be adopted where bessemerizing is done, as the matte can, if required, be tapped direct into the converter.

(*b*) The attached forehearth is used in certain furnaces built after the Pilz type, used for smelting lead-ores, but it is not much in vogue. The lining of forehearths must be suited to local conditions. Where the slag is siliceous and scanty, clay or loam, mixed with chopped straw or horse manure, is cheap and satisfactory. With a ferruginous and abundant slag, a firebrick lining may be necessary.

(8) *Furnaces with Inside Crucible, and no Forehearth.*—These may possibly be advantageous in smelting charges, hard to fuse, and yielding a small quantity of high-grade matte, as the higher temperature promotes better separation.

TABLE VI.—HEIGHT OF BLAST-FURNACES.

Determining cause.	Height.	Remarks.
Mattes and basic ores, rich in iron.	Relatively low, 8 to 13 feet.	Because the higher the furnace, the more easily iron is reduced. Thus for smelting cupriferous-pyrites with 3 to 4 per cent. of copper, a common furnace-height in the United States is 10 feet.
More siliceous ores.	13 to 16½ feet.	In the United States, in smelting acid ores, the height preferred does not exceed 14 feet, for fear that metallic iron might be reduced.
Ores containing more zinc than can be slagged off, and therefore requiring volatilization.	Relatively low.	Lest accretions might be found in the upper part of the furnace.
Ores rich in silica, earths, poor in iron, and hard to fuse.	High, the maximum being, say 30 feet.	Exceptionally used, as at Mansfeld, where there is little fear of iron being reduced.
Smelting with charcoal as fuel.	Not less than 20 feet.	The combustion of the charcoal having a tendency to creep upwards, heat would be wasted, if the furnace was low.

11.—Remarks on Blast-furnaces.

(1) *Height.*—Generally speaking, the height of modern furnaces varies from 11 to 30 feet from the floor-level to the throat. Some variations and their determining causes are shown in Table VI.

(2) *Starting Work.*—It is convenient, especially when blowing in on a new, untried ore, to start with a charge or two of good basic slag.

(3) *Charging.*—Fuel and ore are generally spread in successive horizontal layers over the whole furnace-area. Small charges, producing a more thorough mixing of ore and fuel, promote a more highly reducing action than large charges. Coarse material, forming a more porous charge, can be fed thicker than fine. Large and high furnaces require heavier charges of ore and fuel. With charcoal, the heaviest charge is about 3 cwts.; with coke, in large furnaces, it is about 24 cwts., and from 26 to 36 cwts. in the Orford brick furnaces, running on cupriferous-pyrites. Fusible, especially porous material, such as ferruginous slag, basic slag, copper matte or metals may be fed in lumps of 3 to 12 inches in diameter; but a uniform reduction to 3 inches in diameter is better.

(4) *Smelting Fines.*—The use of fines promotes the formation of flue-dust, choking of the furnace, irregular running, foul slags, and increased costs of running. An increase in the area of a furnace greatly augments its capacity for smelting fines; and, in a large Orford furnace, the presence of 15 to 20 per cent. of fines, is said to produce no drawback; even 50 to 60 per cent. of fines may be used, reducing, but not seriously affecting the running. Dr. E. D. Peters, junior, describes the smelting of raw pyrite-fines, technically called green fines, in a furnace of this kind. Ferruginous slag, carrying 1 to 2 per cent. of copper from the concentration-fusion of copper matte, is added, and this roughly covers the cost of its resmelting, while the large percentage of its protoxide of iron neutralizes the silica of the raw fines, which are largely oxidized by the great volume of blast. The matte produced is of very low grade, but is easily calcined and forms valuable flux for siliceous ores. On account of its large quantity, the syphon-tap is necessary. The slag is always very acid, and carries 48 to 55 per cent. of silica.

(5) *Blast.*—A pressure of 8 to 12 ounces per square inch, with a tuyère-diameter of 3 to 5½ inches, appears best suited to the ordinary conditions of copper-smelting. With long-continued, high-pressure blast and an open charge, the heat usually creeps up the furnace, and eventually igniting the gases, produces a flaming throat. The remedy is to lighten the blast, allow the charge to sink 3 to 4 feet below the charging-door, feed in one or more charges of fusible slag, and rapidly refill the furnace with its normal charge. The heated walls are thus cooled, after a few hours of light running. In obstinate cases, cooling the throat with water-spray is advantageous.

(6) *Fuel.*—The percentage of fuel required depends on its quality, the character and size of the charge, altitude of the locality, etc. In water-jacketted furnaces, with good running and fair coke, 1 ton of coke will smelt from 7 to 8·5 tons of charge (ore and flux).

Mr. H. Lang found that the smelting-value of a given weight of hard dry wood in the blast-furnace was to that of the same weight of coke, as 11 to 27 or 1 to $2\frac{5}{11}$. But replacing half the coke by wood almost doubled the flue-dust, reduced the furnace-capacity by one-third, and necessitated a lighter blast. The chief advantages of wood in Mr. Lang's opinion was that more sulphur was burnt off, thus allowing more raw ore to be added to the charge.

Mr. J. W. Neill, of Leadville, Colorado, trying bituminous non-caking and semi-caking coal, in a silver-lead blast-furnace, found that with about 27 to 30 per cent. of semi-caking coal containing 7·72 per cent. of ash, the slags appeared better reduced and hotter, the matte-separation was very good, the fuel-combustion more complete and the furnace-running better, there being less dust, less loss by volatilization, and the furnace-top was cooler, without any diminution of the blast-pressure.

On water-gas as a fuel for blast-furnace, see the writer's article in *The Engineer.**

(8) *Dealing with Chills.*—When the bottom of the furnace is chilling and the upper part fiercely burning, the remedies are: to reduce the blast-pressure, so as to prevent further chilling of the half-fused, cokeless mass on the hearth; to plug every alternate tuyère, so as to give its chilled nose a chance of remelting; to

* August 17th, 1900, vol. xc., page 153.

allow the ore-column to sink several feet; and then to add several full charges of coke and ferruginous slag.

12.—Reverberatory Furnaces for Copper-smelting.

Other things being equal, a siliceous mixture or a charge consisting largely of finely-divided ore would induce the selection of the reverberatory furnace.

A leading feature of the modern reverberatory furnace is the increasing ratio between the area of hearth and fire-box (in large furnaces 15 to 1), and between the areas of the hearth and stack, (in the largest furnaces 30 to 1).

Other features of interest, as illustrating modern practice are enumerated by Dr. E. D. Peters, junior, as follows:—(1) Rapid charging, by lessening the interval between the charges. Rapid spreading of the charge over the hearth, by dropping the fresh charge direct upon a pool of molten matte, kept in the furnace, upon the liquid surface of which, the hot calcines quickly spread. (2) Rapid slag skimming, through several doors simultaneously, and conducting the fluid slag away through launders, outside the building. It is advantageous to begin skimming, as soon as enough charge is fused to give a fairly clean bed of slag. (3) Preheating the air admitted, through channels in the furnace-brickwork. (4) Using hot calcines. (5) Tapping only once a week, or say after twenty-four or more charges, thus keeping the hearth well covered with matte, protecting it against the intensity of the flame, and by its neutral character, preventing the corrosive action of the ferrous oxide in the charge. (6) Accelerating the fuel-combustion by enlarging the flue and stack-areas, by slightly increasing the grate-area, and keeping the live coals close up to the grate-bars. For poor coal, with much ash, forced blast may be advisable. (7) Accelerating fusion, by keeping the furnace-bottom hot. This is done by closing in the vault, or building without one.

13.—Remarks on Reverberatory Furnaces.

(1) *Charging.*—Charging by means of hoppers, especially with hot calcines, is accompanied by much dust, increasing the loss of precious metals. To prevent this dust by checking the draught, a flue-damper may be used, or an opening provided in the stack, opposite but above the flue-entrances.

(2) *Hearths.*—These are preferably made by a double process: first slightly fusible sand over clay is used for the bottom-layer, over which is spread infusible material, the cementation of the particles being effected by repeated smeltings of small charges of fusible material, such as moderately basic slag, till the whole is solidified. This upper hearth, when worn out, can be easily removed. All material should be quite free from organic matter. In the case of charges sticking to the bottom, the best remedy is a large charge of pyrites, and the large body of low-grade matte, so formed, quickly cleans the hearth.

(3) *Dust-chambers.*—Where the charge is rich, especially in precious metals, dust-chambers are advantageous, but they must not be allowed to interfere with the draught.

(4) *Flues.*—The furnace-flue should be narrow at its junction with the furnace, expanding as it enters the stack, so as to have there at least 50 per cent. greater area.

(5) *Stack.*—If a separate chimney is used for each furnace and there are no surrounding hills, etc., to check the draught by down currents, a height of 65 feet is enough. But if one stack is used for several furnaces, 120 feet may be needed. High chimneys should be circular and built from the inside; those up to 80 feet high may be square, and built from the outside.

14.—Wet Extraction of Copper.

This method is applied to:—(1) Ores that are too poor to smelt: under favourable conditions, to ores with as little as $\frac{1}{4}$ to 1 per cent. of copper; and (2) products containing copper, silver and gold.

The ores amenable to wet treatment include: (*a*) Copper in the form of oxide, carbonate, sulphate, and phosphite, or arseniate, can be dissolved by cheap solvents, such as ferric sulphate. (*b*) Copper in the form of sulphide, admitting very slow and imperfect extraction by cheap solvents, has first to be converted into a sulphate or a chloride, soluble by cheap solvents, such as water, hydrochloric or sulphuric acid, or metallic chlorides.

In all cases, the copper is precipitated, as metallic copper, by means of iron; or exceptionally as sulphide by sulphuretted hydrogen; or as hydrated oxide, by suboxide. The iron is usually metallic, wrought iron, pig-iron, sponge-iron, bears, etc. Tin-plate clippings also can be used; if the copper is in solution as chloride, the tin can be separated as oxide.

(1) Dealing with the above more in detail, it may be said that for ores containing oxide or carbonate of copper, such as ores of cupric oxide, azurite, malachite, arseniate of copper, the solvents used are sulphuric acid, hydrochloric acid or ferrous chloride. The two former are very energetic, and if low in price, should be used in preference to the slower ferrous chloride.

A necessary condition for the employment of acids is that the ores should not contain notable quantities of other bodies, especially carbonates, soluble in acids. Carbonates, other than those of copper, are prejudicial also to the use of ferrous chloride. Regarding the action of these various solvents it is noteworthy that:—

(*a*) Sulphuric acid readily dissolves cupric oxide, azurite, malachite, and arseniate of copper; somewhat less readily, phosphate of copper. The acid is applied as such, or as sulphur dioxide, nitrous fumes, and water-vapour.

(*b*) Hydrochloric acid is preferable to sulphuric acid, as it is less liable to form basic salts. The solutions, therefore, contain little free acid, and thus require less iron to precipitate the copper than solutions containing sulphate of iron. On the other hand, hydrochloric acid attacks oxide of iron more energetically, and accordingly is less suited for treating ores with much ferrous oxide.

(*c*) Ferrous chloride is suitable for cupric oxide or copper carbonates; cuprous oxide may be treated, if first converted into cupric oxide by ignition in the presence of air. The original Hunt-Douglas process has been modified by dissolving the copper by dilute sulphuric acid, and then adding ferrous or calcic chloride to the solution. This method has the advantage that ferric hydrate is not formed, nor is silver dissolved by the weak sulphuric acid, and the copper-precipitation requires little iron.

(*d*) Ferric sulphate may be used in combination with sulphuric acid.

(2) For ores, mine water, etc., containing copper as sulphate, the copper is precipitated from solution by iron. Sulphuretted hydrogen may be used, when iron is not obtainable. The precipitated (cemented) copper, sulphide of copper, is dried in filter-presses, and either roasted in the English reverberatory, or converted by hot air-blast into oxide, and then smelted for coarse copper.

(3) For ores containing copper as sulphide, the first operation

is to convert this into soluble sulphate, or oxide, or chloride. The first transformation is effected: —

(*a*) By weathering, without calcination. This natural oxidation is promoted by repeated leaching, pouring over the heaps the acid ferric-sulphate liquors, left when the copper is cemented. Generally several years are needed to obtain even a moderate proportion of copper in the form of sulphate. The extraction is somewhat imperfect, and capital is locked up for a long time.

(*b*) By slow calcination—such calcination requires the ore to contain proportionately large amounts of iron-pyrites and small amounts of copper-pyrites. After calcination and leaching, the heap is allowed to weather, so as to convert the residue into sulphate. If the ores are free from gangue, do not decrepitate, and have sufficient copper, the roasting is so conducted as to concentrate the copper sulphide in a kernel, while the sulphate remains in the porous crust, consisting chiefly of iron oxide, and is leached out. The kernels are smelted.

(*c*) By calcination with sulphate of iron or other easily decomposable sulphates, such as sulphate of alumina, thus converting the greater part of the copper into sulphate. The calcination is done in heaps. The ore, say a poor copper-pyrites, is crushed fine, made into a stiff paste with cementation-liquors containing sulphate of iron, moulded into bricks, dried, and built up into heaps. The leaching is done with cementation-liquors from which the copper has been precipitated.

(*d*) By treating the ore with nitrate of iron (Perrino process).

(*e*) By treating the ore with ferric-sulphate solution—a method proposed for decomposing sulphide of copper for electrolytic extraction.

The second conversion, namely, the transformation of copper-sulphide into oxide, is effected by calcining the crushed ore.

The third change, namely the conversion of sulphide into chloride is effected either in the wet way, by treating the ore either with ferric or ferrous chloride and hydrochloric acid. The process is slow and advisable only when fuel is dear, or the fumes of a chloridizing roast cannot be allowed to escape into the air. The conversion of copper sulphide into chloride by ferric chloride is applied at Rio Tinto to cupriferous pyrites, with about 2·68 per cent. of copper, and is there known as the Dötsch process. The result is cupric and cuprous chloride dissolved in ferrous chloride,

and ferric chloride. After precipitation by iron, the ferric chloride is regenerated by iron. About 1·34 per cent. of the copper is converted into chloride, and leached out in four months. Of the rest, 0·86 per cent. of copper is extracted in two years more, and the residual 0·48 per cent. of copper is lost. Attempts have been made at Rio Tinto to shorten the chlorination by first digesting the ore with ferric chloride in vessels, and then treating it in heaps. As the Dötsch process only slightly attacks iron-pyrites, the leached ore can still be used for sulphuric acid manufacture. In dry chlorination, the calcination should be conducted so as to produce the minimum of copper oxide and cuprous chloride, as these, being insoluble in water, require to be leached by acids. The necessary conditions for this method are that the sulphur does not exceed 1½ times the equivalent of copper present, otherwise too much salt must be used and the calcination too much prolonged. Again, the ore must not contain more than 6 to 8 per cent. of copper, otherwise the whole of the sulphide will not be decomposed. Lastly, the temperature must not exceed low redness, otherwise too much cupric chloride would be volatilized.

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The President (Mr. J. G. Weeks) proposed a vote of thanks to Capt. C. C. Longridge for his comprehensive paper.

The resolution was cordially approved.

Mr. Jacob Sharp's paper on "A Flash of Lightning at the Lambton Colliery, D and Lady Ann Pits, on October 2nd, 1900," was read as follows:—

A FLASH OF LIGHTNING AT THE LAMBTON COLLIERY, D AND LADY ANN PITS, ON OCTOBER 2ND, 1900.

By JACOB SHARP.

Description of Shafts, etc.—The D Pit is a downcast shaft, lined with firebrick lumps, and sunk to the Five-Quarter seam at a depth of 300 feet. The shaft is used for winding coal, and is fitted with steel-rail guides, fixed in steel sleepers attached to wooden buntons. The winding-ropes are of steel, 4½ inches in circumference. There is also in the shaft a wrought-iron pipe (9 inches in diameter) conveying compressed air into the mine. Safety-lamps are solely used in both mines.

The Lady Ann pit and upcast shaft, 12 feet in diameter, passes 135,000 cubic feet of air per minute by a Waddle fan. This shaft is used for coal-drawing, etc., and is fitted with wooden guides. There are three ranges of pipes in this shaft: steam-pipes, 7 inches in diameter; exhaust steam-pipes, 9 inches in diameter; and water-pipes, 6 inches in diameter. The hanging-on is at the same level as in the D Pit. The steel winding-ropes are 4¼ inches in circumference.

On the road, G, between the pits, there is a line of rails for traffic; on the road, F, there is a range of cast-iron pipes, 6 inches in diameter, used for conveying compressed air from the D Pit to the workings beyond the eastern curve, E (Fig. 1).

The hauling-engine, A, at the Lady Ann pit, is set off the shaft at a depth of 138 feet below the hanging-on.

The writer, at 3·45 p.m., on October 2nd, 1900, was standing near to the D pit, when a terrific crash of thunder broke immediately above him, the lightning being intensely vivid, and such as he had seldom experienced. Upon consulting with the officials about 5 p.m., he received the reports given herewith:—

The onsetter at the D pit stated:—I was signalling by the down rapper to the Hutton seam, below the Five-Quarter seam, when I received a severe shock in my arm. Upon leaving the rapper and turning round to sprag the wheels of a tub, I saw what I thought was a lightning flash, running along the com-

pressed-air pipes: it seemed to travel about 50 or 100 feet to the north and then die out. I was sure it was lightning, as I heard it thundering very heavily. This occurred about 3·50 p.m.

The hauling-engineman stationed at the point, A, stated:—At or about 3·40 p.m., as I was bringing the full set of tubs into the shaft-siding, standing with my left foot on the tail-drum brake-lever and the steam-regulator in my right hand, I received a shock which affected me in my legs and arms mostly. I also noticed a bright blue light, flitting about the drums in the engine-house.

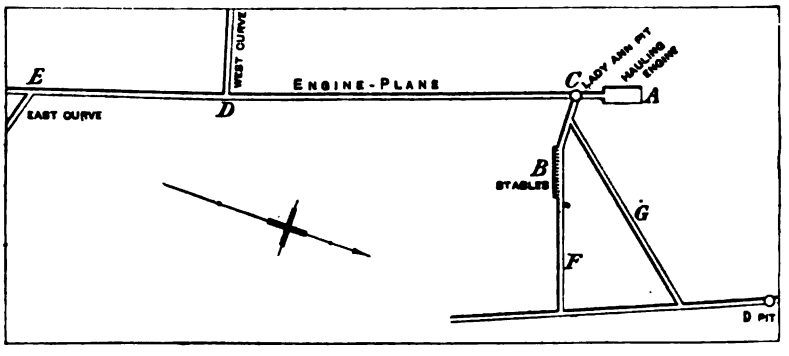

FIG. 1.—PLAN OF FIVE-QUARTER SEAM, SHOWING THE MAIN ROADWAYS, ADJACENT TO THE D PIT AND LADY ANN PIT, LAMBTON COLLIERIES. SCALE, 500 FEET TO 1 INCH.

The horsekeeper, who was in the stables, B, stated:—About 3·50 p.m., while cleaning one of the ponies in the stable, I noticed something which appeared to drop from the roof and burst upon the floor giving a bright light. About 5 minutes later, I again observed a similar flash, but much brighter than the former, and a noise similar to the report of a revolver which seemed to come from the water-pipes. I was alarmed and went out of the shaft, and acquainted the overman with the occurrence.

The overman, who was standing at C, stated:—At 3·45 p.m., I was standing at the south side of the Lady Ann shaft and facing the stables, when suddenly I heard a report like a heavy mall being struck upon the air or water-pipes, and at the same time saw a very bright light. Thinking that it might be some accident to the pipes, I went along the shaft-siding to examine the pipes, and while doing so the horsekeeper came up and reported a similar occurrence in the stables.

A workman, attending to the offtake and rapper signals on the engine-plane, at D, stated:—At 3·50 p.m., I was standing near the rapper-lever as the full set of tubs was coming out of the south landing, when I observed what I thought was lightning running along the rails, and it seemed to jump up to the roof close to where I was standing and to travel in-bye. About 7 or 8 minutes later, I was riding on the full set of tubs and on entering the shaft-siding, I again saw a flash of light running along the tail-rope. It seemed to cross the road and strike against the wall-side a few feet away, producing a noise like a sharp clap of the hands. When I came to the lads employed in the shaft-siding, they asked me whether I had seen the lightning running along the engine-plane?

The engine-plane man, who was stationed at E, stated:—I was stationed at the east off-take, from 3·30 to 3·50 or 4 p.m., and saw no trace of any fire or lightning at this point, which I certainly should have noticed had it passed me.

There are no wires erected about either pit for electric lighting or telephoning, hence there can have been no conduction from that source. The writer, in submitting the above statement, desires to hear the opinions of members as to the possible results in an upcast pit, where gas may be given off at low atmospheric pressures, from lower and exhausted seams, as in the case of the Hutton seam, in this district.

Mr. Sydney F. Walker wrote that Mr. Sharp's report of the occurrence of a flash of lightning at the Lady Ann pit, was very interesting, inasmuch as it furnished, in a strikingly graphic manner, an illustration of what actually took place whenever a discharge of high-tension electricity occurs. As pointed out in his (Mr. Walker's) paper on alternate currents, when a current starts on a conductor, before it can reach the end of the conductor it has to furnish the magnetic field surrounding the conductor, and to charge the condenser of which the conductor forms one coating. Where the tension is very high—50,000 volts and upwards—the charge is distinctly visible on the outside of the conductor, and represents an actual consumption of energy, quite apart from the charge locked up in

the condenser. The light seen by the different officials would be undoubtedly the charge forcing its way along, in the operation of charging the condensers of which the different pipes formed one side, the other side being probably formed by the coal-seam itself. It is not often that visual evidence is obtained of this gradual charge. We have been so long accustomed to regard everything connected with electricity as instantaneous, that it comes as a sort of shock to be told that any electric phenomenon is gradual, and takes a sensible time to carry out. Yet what the officials of the Lady Ann pit saw was the outward and visible sign of one portion of what takes place whenever a current of any form starts to pass through a conductor. In this case the effects were greatly intensified and the speed probably increased, owing to the high tensions present.

The PRESIDENT (Mr. J. G. Weeks) said it was advantageous to print Mr. Sharp's record in the *Transactions*. It was by no means the first time that lightning had descended a pit. In the Tanfield Moor case,* the Kimblesworth case,† and in the West Thornley case,‡ the matter was very fully discussed, and it was considered that the only practical precaution was to erect, near the pulley-wheels, a lightning-conductor, and to be sure that it led either into a running stream or into good earth to carry away the electric fluid. He had pleasure in proposing a vote of thanks to the writer for his interesting paper.

Prof. H. LOUIS seconded the resolution, which was cordially approved.

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* *Trans. N.E. Inst.*, vol. xxx., page 31.

† *Ibid.*, vol. xxx., page 129. ‡ *Ibid.*, vol. xxxvi., pages 47 and 86.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JANUARY 19TH, 1901.

MR. T. V. SIMPSON IN THE CHAIR.

DISCUSSION OF MR. NORMAN M. THORNTON'S PAPER ON "LONGWALL METHODS IN THE EASTWOOD DISTRICT, NOTTINGHAMSHIRE."*

The CHAIRMAN (Mr. T. V. Simpson) remarked that Mr. Thornton mentioned that in each gate-road "as an additional precaution, a safety-lamp is suspended on the inbye-side of the hurdle-cloth, as near to the roof as possible." Was the lamp placed there to light the place, or for any other purpose? He thought that in a gassy pit it was a most dangerous place to hang a lamp.

DISCUSSION OF MR. THOMAS V. SIMPSON'S PAPER ON A "SAFETY-LAMP CABIN AT HEWORTH COLLIERY."†

Mr. T. V. SIMPSON remarked that at a colliery using 1,600 safety-lamps, he noticed that 14 boys and men were engaged in cleaning the safety-lamps, and 10 men were employed at Heworth colliery. Each man tried his lamp to ascertain whether it was fit to take into the mine. One great difficulty was to get the safety-lamps given out and lighted in time. Any lamp extinguished in the pit was re-lighted at a station, appointed for that purpose.

The meeting then terminated.

* *Trans. Inst. M.E.*, 1900, vol. xix., page 125. † *Ibid.*, vol. xx., page 17.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,
HELD AT THE UNIVERSITY COLLEGE, NOTTINGHAM, DECEMBER 15TH, 1900.

MR. MAURICE DEACON, PRESIDENT, IN THE CHAIR.

The SECRETARY announced the election of the following gentlemen:—

MEMBER—

Mr. CHARLES JOHN DIDHAM, Colliery Owner, Hasland House, Chesterfield.

ASSOCIATES—

Mr. SAMUEL DAY, Under-manager, Grassmoor, Chesterfield.
Mr. T. N. LIMB, Under-manager, Heath, Chesterfield.
Mr. G. H. MARSHALL, Under-manager, Heath, Chesterfield.
Mr. WM. MELLORS, Under-manager, Denby Hall Colliery, Marehay, Derby.
Mr. WM. STEVENS, Enginewright, Victoria Street, Ripley.
Mr. THOMAS TATE, Enginewright, Heath, Chesterfield.

STUDENT—

Mr. PERCY G. VICKERS, Hill Top, Eastwood, Notts.

DISCUSSION ON MR. W. H. HEPPLEWHITE'S PAPER ON "THE HEPPLEWHITE TAPERED PIT-PROPS AND BARS."*

Mr. A. S. DOUGLAS (Hucknall Torkard) said that during the half-year ending June, 1899, when tapered props were not in use, the tonnage sent to bank per new prop was 5·9, while for the half-year ending November, 1900, during which tapered props were wholly used, the tonnage was 8·9. He had now used tapered props exclusively at the Hucknall Torkard collieries for 18 months, and statistics proved that a decided saving had followed the use of tapered props, accompanied by a great improvement in the condition of the stalls.

* *Trans. Inst. M.E.*, 1900, vol. xix., pages 8 and 106; and vol. xx., page 214.

Mr. J. F. LEE (Glapwell) said that his experience in the use of tapered props was limited. In one district of seventeen stalls in the Hard coal-seam, the cost over a period of three months, for ordinary props was 1d. per ton; and for one month the cost for tapered props in the same district was 0·56d. per ton.

Mr. W. WRIGHT (Eastwood) said that at the colliery where he was employed, in the Soft coal-seam, 2,441 tapered props were set, and 10 had been broken; in the Hard coal-seam 1,657 props were set, and 13 had been broken; and there was a total of 23 broken props out of 4,098 tapered props. The tapered props could be set several times. He considered that the use of tapered props was economical in a seam with a hard floor.

Mr. H. RICHARDSON HEWITT (H.M. Inspector of Mines, Derby) said that from observations at various collieries he could not find that tapered props curled up at the foot in the regular way shown by Mr. Hepplewhite in Figs. 11 and 12.* If a prop did so, it would be an easy matter to place a lid under the tapered prop for its second setting. Instead of this, the burring occurred unevenly, one side of the taper being much deformed, while the other side might keep its original shape. In cases of this kind, which were very numerous, it was quite impossible satisfactorily to re-set the tapered prop, unless it was again tapered by the machine. In some stalls, the workmen were supplied with a saw and an axe, with which they trim the ends, but it could not be satisfactorily done; and further, No. 22 of the general rules of the Coal-mines Regulation Act prescribed that "suitable timber shall be provided at the working-face," he presumed by the owners, and not by the workmen. If these deformed tapered props were set on one or more foot-lids as suggested† they would be more liable to be pushed out by any weight coming upon them, than a whole prop such as colliery-managers are accustomed to use. Lids cost 3d. each, and when used at the foot of a prop, they are seldom recovered. It would be useful if members could quote the costs of timber, including props, bars and lids, when ordinary and tapered props were in use, instead of the tons of coal raised per new prop. In addition, he would like information as to how many times tapered props had been re-set in the

* *Trans. Inst. M.E.*, vol. xix , Plate I., page 14.

† *Ibid.*, vol. xix., pages 10, 12 and 20.

same position; and if they were re-set several times, it appeared to him that ordinary untapered broomsticks might have been used to hold up the roof.

In two cases that had come under his notice he found that tapered props broke either at the top of the tapered portion, or higher up, in the same way as an ordinary prop. One case referred to the Silkstone seam of Derbyshire, and the other to the Roaster seam of Leicestershire, each with a hard roof and a hard floor at the particular places to which he alluded. As the depression of the roof, 6 feet from the face, varied from 2½ inches to 7½ inches,* he would ask Mr. Hepplewhite to explain his method of calculating the length of taper to be applied to the props.

Experiments showed that tapered props began to burr at a pressure of 15½ tons:† it might be a serious matter to allow a roof to break at that pressure, whereas an ordinary prop could have been used to carry over 30 tons of top weight, probably avoiding a break in the roof, and its consequent dangers, by using the additional support. In some mines, iron- or steel-props with a hard lid were used, and were very successful in long hard roofs. In these cases, as much roof as possible is kept up as long as it is required, whereas Mr. Hepplewhite practically recommends that the roof should be allowed to fall, and that facilities should be afforded for its falling, within certain limits. A collier will tell you that the sooner the waste breaks down the better it is for him; and next, that the sooner he can throw the weight from the stall over the coal-face, the easier will it be for him to get coal. Where this action is properly performed, there is no necessity for the use of explosives in the coal, and the difficulty is rather to keep the coal in position until it is required.

Mr. J. H. W. Laverick (Alfreton) said that the roof in one district was so heavy that they were seldom able to set an ordinary prop more than once. When tapered props were introduced it was found that some of them could be set as often as seven times, and a broken or split prop was almost unknown. The stallman notched the props, each time that they were re-set, and it was found that tapered props were frequently set four, five, six and up to seven times. During 22 weeks ending November, 1899, in

* *Trans. Inst. M.E.*, vol. xix., Table I., page 13. † *Ibid.*, vol. xix., page 19.

a seam with a hard floor and a hard roof, the number of tons raised per ordinary prop was 4·97, as against 6·7 tons per tapered prop during 22 weeks ending November, 1900, shewing a saving of about 25 per cent. For the same periods, in a seam with a comparatively soft floor and roof, the produce per ordinary prop was 5·5 tons last year, against 6·5 tons per tapered prop this year, which represents an economy of about 15 per cent.

At collieries, where coal-seams of different thicknesses were being worked, timber could be sent from the thicker to the thinner seam. The whole of the timber used in one of the thinner seams was supplied from thicker seams, and a new prop was rarely sent into the thinner seam. In the thicker seam, 8 tons of coal were produced per new tapered prop, the fuzzed props were sent to the surface, re-tapered, and sent into the thinner seam, where a further tonnage of 5·7 per tapered prop was obtained.

He might also mention that he seldom saw a split or broken prop in the workings, and the timber brought out of the pit (to be cut into lids or sleepers) was of superior quality. This saving was an important item which had not been referred to by other speakers.

Mr. W. H. Hepplewhite (H.M. Inspector of Mines, Nottingham), replying to the discussion, said he was afraid that the props seen by Mr. Hewitt had not been properly tapered, or had been set on an uneven surface, otherwise the burring of the tapered end would have taken place regularly. But the object of the tapering had been accomplished, as the prop had been saved from breaking; and it was of little importance how the burring took place, so long as the prop was not broken. The original idea of tapering props was to make them as nearly round as possible by a proper machine, so that each year's growth would be intersected, and would when subjected to excessive weight, curl up as the pressure increased. Up to the present time, the circular saw had been used, the attendant being instructed to make the tapering as round as possible: but it could not be expected that the tapering would be mathematically correct. At collieries, where tapered props were used, the unsuitable and badly-burred props were sent out to the gate-road, where they were trimmed by a specially appointed workman, who made periodical visits to each gate-road. Unevenly burred props should be trimmed before

being set upon two lids. The length of the taper upon props had been determined by scientific and practical tests, and he never recommended—irrespective of the diameter of the prop—that the thin end of the tapered prop should be reduced to less than 3 inches, which was as thick as some of the props used in the Midland mines-inspection district.

Props, set immediately following a web of coal, were only intended to support local stone and not the weight of the superincumbent strata to the surface. In a case where props following a web of coal were set in all directions 4½ feet apart, there would be 4 tapered props in an area of 20¼ square feet, and they would uphold a dead-weight of over 60 tons; and as the weight of the roof increased, burring would ensue, and the strength of the props would increase to over 120 tons. It must not, however, be assumed that there were 60 tons of dead-weight resting on props as soon as they were set. The depression of the roof was gradual and almost irresistible, and tapered props were intended to allow of this gradual depression without being broken. If it were possible to ascertain accurately how much dead-weight a prop is called upon to sustain under normal conditions, when set immediately after the buttock, it would be an easy matter to set props of sufficient strength to support the roof safely. But such a thing is impossible. Table I.* showed the depression of the roof at certain distances at right angles from the coal-face, and it would be seen that measurements, taken in the Top Hard seam, near the buttock, varied from 2½ inches to 3½ inches in 6 feet, and it was about the same in the other seams. It must therefore follow that the depression of the roof commenced over the coal-face, and formed a long curve back into the waste; that the farther the props were from the coal-face the more superincumbent strata they were called upon to sustain, and consequently the greater was the destruction of timber. It would be interesting if some mining-engineer, who used double rows of props after a web of coal, were to ascertain whether there were more broken props along the coal-face than on the gobbing-side: in the case of the gobbing-side, the roof had settled 2 inches to 3 inches before the props were set, and the props next the coal-face were bound to get the pressure when the adjoining web of coal was removed.

† *Trans. Inst. M.E.*, vol. xix., page 13.

In conclusion, he desired strongly to urge, where the conditions were favourable, the use of tapered props. In gate-roads, there would be a saving in props from breakage; and the ripping-lip would be rendered safer for the workmen, who had to pass and repass under it; because the props would be whole and upright, and the roof probably unbroken. Again, where bars were set with props under them, or where bars alone let into the sides immediately followed the ripping-lip, or strong and costly props were set at the junctions of gate-roads, or timber set along old faces, airways, gate-roads, or any place where they were left principally for ventilation-purposes—in all these cases, tapered props, if properly set, would ensure an enormous saving of costly timber and costly labour in the renewal of broken timber.

In the Midland mines-inspection district, there were 314 working coal-mines, and from his own personal knowledge, 107 of these mines, or 30 per cent., could use tapered props with advantage. In the United Kingdom, excluding Ireland, there were 3,392 coal-mines: if they assumed that the same proportion could use tapered props as in the Midland mines-inspection district, and that the timber-bill of these coal-mines was £2,000,000 per annum, and if the saving was only 25 per cent., then they had the startling fact that tapered props and bars would effect an economy in the timber-bill of £500,000 per annum.

Mr. A. S. Douglas said that a tapered prop might be set two or three times in a district; and when unfit for use in that district, it could be sent into a second district in the same seam, and then into a thinner seam. The timber used in the Waterloo seam at Hucknall Torkard colliery was taken from the Top Hard seam, and no new props were used. There was also an advantage in transferring the props from the Top Hard to the Waterloo seam. The props were 5 or 6 inches in diameter, whereas if timber was bought specially for use in the Waterloo seam, it would probably be thought that a diameter of 3 or 4 inches would be large enough. The props were thus considerably stronger than they would be if specially bought for the thinner seam, and a smaller number of them would support an equal area of roof. The timber in the Top Hard seam was usually set four or five times; then it was sent to the Waterloo seam, where it would be set two or three times more; and it would

ultimately be cut into lids or sleepers, because the bulk of the timber was still undamaged when sent out of the pit.

The PRESIDENT (Mr. M. Deacon) remarked that, whatever their various opinions might be as to the merits or demerits of tapering props, they would all agree that Mr. Hepplewhite had introduced a most interesting subject for discussion. He had observed that tapered props, when in use, did not break in the middle. If the seam was of uniform thickness and the burring of the taper gradually shortened the length of the props, it was of little more value for re-setting than a prop broken through the middle; but if they had a thinner seam, or a thinner part of the same seam, to which they could transfer a prop when the first taper had become crushed, there was no doubt an advantage in using tapered props. If Mr. Laverick had been able to set one prop seven times, it must have been because he had seams in his pits of seven different thicknesses.

DISCUSSION OF MR. B. McLAREN'S PAPER ON "PREVENTIBLE COLLIERY FATALITIES,"* AND MR. GEORGE FARMER'S PAPER ON "MINING ACCIDENTS AND THEIR PREVENTION."†

Mr. B. MCLAREN said that there was an apparent discrepancy between one of the sentences on page 22 and the first paragraph on the following page.‡ The former sentence stated that "In the case of those accidents deemed preventible under the heading of explosions of gas or coal-dust, no accidents have been included which would be prevented by the abolition of the use of naked lights in coal mines;" while on the following page it was stated that "of the 58 deaths, 15 deaths (13 accidents) arose through persons entering with naked lights into unexamined disused workings containing fire-damp." He intended to convey that no accidents due solely to the use of naked lights had been included, but that those due to the misuse of naked lights were included; thus, if a naked light was taken into gas, and the gas exploded, he considered that it was a preventible accident, and it was therefore included in his statistics.

On page 24, sub-section (*d*) should read as follows:—

"(*d*) *Using a Ringer-and-chain instead of a Hammer or Pick*

* *Trans. Inst. M.E.*, 1900, vol. xix., page 21.
† *Ibid.*, vol. xix., page 72. ‡ *Ibid.*, pages 22 and 23.

for drawing Props, Bars, Sprags, etc. (38 deaths or 12 per cent.). —In the Midland mines-inspection district, of the total number of preventible fatalities due to falls of ground, 11 deaths, or 39 per cent., were due to the non-use of the ringer-and-chain instead of a hammer or pick for drawing props, bars, sprags, etc."

At the top of page 31, the first paragraph should have been indicated as a quotation from remarks made by Mr. A. H. Stokes on April 2nd, 1898.*

Mr. G. J. Binns (Derby) said that although from its title Mr. McLaren's paper is restricted to accidents causing death, he refers to non-fatal accidents;† and inasmuch as many injuries which do not immediately cause death, eventually either do so, or at any rate shorten life, he (Mr. Binns) proposed to discuss colliery accidents generally. And there is every reason to extend thus the scope of the discussion, because many casualties, although not followed by loss of life, are perhaps hardly less, or no less, deplorable. He referred to such cases as spinal disablement, loss of an eye, or both eyes, and other irreparable injuries.

Much might be done, not only in preventing fatalities, but in shortening the duration of disablement, by the exercise of more care after the occurrence of the injury. Engineers are unfortunately familiar with the culpable neglect amongst miners who have received a wound, a neglect in many cases due no doubt to the hardihood of men who think but little of a hurt, which many people would consider severe. It may indeed at the time seem trifling, or even be really of no importance, but, it may by neglect and inattention cause blindness, blood-poisoning, and not infrequently death. He (Mr. Binns) was quite sensible of the enormous value of ambulance or first-aid training, and regretted that more miners were not familiar with it; only recently artificial respiration was tried on a boy who had received a severe injury to his head, from which blood exuded copiously; and in another case, where a man received an electric current which should not have done him any serious injury, but by which respiration was arrested, no efforts towards resuscitation were made. It should be widely known that, even more than the apparently drowned, the apparently electrocuted should be persevered with for many hours.

* *Trans. Inst. M.E.*, vol. xv., page 207.

† *Ibid.*, vol. xix., pages 21 and 29.

The neglect, however, arises not always immediately, but frequently after the patient has begun to get about; and, among the causes of disaster by immediate negligence, the first place must be given to ophthalmic cases, which are especially noticeable from their grievous effects on the welfare of the men. Dr. Simeon Snell, of the Royal Infirmary, Sheffield, had kindly sent him (Mr. Binns) a copy of his pamphlet on *The Prevention of Eye Accidents occurring in Trades*; and he mentions that the secretary of the Miners' Permanent Benefit Fund stated that in 15 years, out of 48,262 accidents which rendered miners unfit for continuing their work, 2,506, or 5·19 per cent., were due to injuries to eyes. Also that the Equalized Druid Society, in 57 cases of permanent incapacity, had 7, or nearly 12·3 per cent., due to eye-casualties. Personally he had taken a recent period during which 954 accidents of all sorts were reported to an Indemnity Company, and of these 41, or 4·297 per cent., were injuries to the sight. Dr. Snell strongly recommends—it should be mentioned that his paper deals principally with the metal trades—some form of protection for the eye, and the provision of properly sterilized instruments for removing foreign bodies, to prevent wounds in the eye from becoming septic. As regards eye-protectors, he (Mr. Binns) knew that in several cases men engaged in heading in collieries, had provided themselves with spectacles for this purpose.

Regarding the neglect so frequent immediately after the wound has taken place, a valuable suggestion had been made by Dr. Gray, of Mansfield, that any abrasion should be dressed at once with antiseptic lotion and clean lint instead of with the usual snap-bag and cold tea.

He (Mr. Binns) had taken Mr. McLaren's figures as correct, and had perused them with interest. At the same time, it appeared a difficult thing to decide which accidents are preventible and which are not, because, it must be admitted that every one could have been prevented by some means or other. Mr. McLaren's paper was written upon an interesting subject, and must have involved an enormous amount of labour. He concurred with Mr. McLaren's remarks as to the study of the reports of H.M. inspectors of mines, and the recommendation made by Mr. H. Hall that they should be more accessible and more widely distributed. H.M. inspectors of mines naturally become

specialists in the prevention of accidents, while the attention of colliery-managers is diverted by a thousand cares and responsibilities.

It appears that there are at least two important causes of accident to which attention should be called, but he (Mr. Binns) was uncertain whether any fatalities were owing to them during the period dealt with by Mr. McLaren; one is the danger arising from circular saws, and the other the possibility of death from electric shock, to which attention had already been directed.

Mr. A. H. Stokes (H.M. Inspector of Mines) said that the subject of the early treatment of apparently trifling injuries was one which deserved attention. If a man received a wound in the pit the first thing that he did was to wrap it up in some way or other, a dinner-bag being usually the nearest article; but at any rate something unsuitable was occasionally utilized. He believed that a great many lives were lost by blood-poisoning. Two years ago, Mr. H. R. Hewitt was very ill from an injury received in a pit, and he (Mr. Stokes) had always thought that the serious effects were due to septic matter which had entered the wound at the time. Mr. Hewitt was neither negligent nor careless in dealing with his wound; but his case proved that, even with great care, there was a possibility of wounds becoming dangerous. He should like to impress upon the members the necessity of having wounds antiseptically dressed immediately after they were sustained. Antiseptic dressings should be kept at every colliery, and the wound should be dressed before the workman went home.

Greater attention must be devoted to the dangers attending the use of electricity in mines and especially to the covering of the terminals of the machine. Cables were taken into mines so clothed that they could be handled with impunity, but at the point where men were frequently screwing up bolts or attending to the machinery, the terminals were exposed.

Mr. William Maurice (Tibshelf) said that Mr. McLaren's and Mr. George Farmer's papers were very useful, but they might have been supplemented with lists of accidents and précis details, which, as Mr. M. H. Mills had observed, would have been much more valuable than abstract speculation, as a guide to the prevention of injuries. To know exactly how an accident happened was to have the power of limiting the frequency of its recurrence.

There were indications that the greater number of miscellaneous accidents occurred during special work necessitated by breakdowns of various kinds, rather than in the course of a person's normal occupation. Many of these mishaps, though often trivial in themselves, not infrequently necessitated more or less prolonged abstention of the injured person from his work. The application at the mine, of clean water and simple antiseptic dressings, should lessen the possibly serious development of many minor injuries.

Mr. Farmer spoke of rendering harmless all issues of fire-damp "by a constant and adequate ventilation."* Mr. E. W. Thirkell had already dealt at considerable length with the question of "adequate ventilation,"† but it had elsewhere been shown that a limiting maximum, as well as a minimum, velocity of air in mines was also a condition of safety. Respecting coal-dust, Mr. Farmer passed over Mr. W. Galloway's clay-dust method of eliminating danger, in the space of half-a-dozen words.‡ He (Mr. Maurice) thought that a measure which fitted so excellently with man's human nature, and which, as it were, attained an end without the provision of means—in many mines, at least—was somewhat worthy of more extended consideration. The method was both easy and cheap, and he believed was much safer than the watering schemes, which, though plausible on paper, were so ineffectual in the mine.

On the whole, the problem of preventing mine-accidents was not so much a matter of designing and applying safety-devices as of providing better light. There were three primary and essential conditions for safety—space, order and light. Where one of these conditions was wanting, the other two necessarily acquired greater importance; and in underground work, where both space and light were but too frequently minor quantities, then order, and all thereby implied, became of paramount consequence. Material improvement in the illumination of mines was doubtless a development of the near future. Order seemed to divide itself into systematic organization, which was the affair of the management; and appreciation of system, which was the affair of the workmen. The objections, sometimes

* *Trans. Inst. M.E.*, vol. xix., page 75.

† *Ibid.*, 1897, vol. xiii., page 389.

‡ *Ibid.*, vol. xix., page 75.

open, often occult, which were almost invariably raised by some men (a rapidly decreasing number, it was pleasant to note) towards every measure of prudence, could only be overcome by the exercise of patience, firmness and persuasion, on the part of those in authority.

Increased educational facilities would doubtless tend to direct workmen towards a juster recognition of their responsibilities, but he (Mr. Maurice) could not see that technical education was quite so valuable as might be inferred from the observations of Mr. McLaren and Mr. Farmer. As a natural sequence to effective primary education, a course of technical instruction was unquestionably a good thing. It appeared, however, that the country, in its scramble to bring itself into line with other commercial nations had laid in a large stock of mental food, which could be administered in small doses and be depended upon to take prompt effect. It forgot that the average intelligence was not equal to the task of assimilating its extract of science. Much of the money devoted to mining and similar classes was wasted, on account of the number of students who, by reason of defective primary instruction, were unable to pick up even the rudiments of the subjects taught. Technical education called for a trained mind, which primary education largely failed to provide. What was therefore likely to be of value in mining villages was the encouragement of such interests and recreations amongst children as would tend to the development of their mental and moral well-being, and so do for them what should be, but broadly speaking was not, done at school. In the summer months, field-classes in geology, botany, etc., might for example be conducted. The practice of art handicrafts, again, was a means of awakening interest, of developing the perceptive faculties, and of really educating children, which merited much more attention than it had hitherto received. Artistic craftsmanship was eminently adapted to the needs of village-communities, serving, as it did, not only the purpose of improving the hands and eyes and brains of the actual workers, but sending out into their homes an irresistible influence for "sweetness and light."

Mr. T. A. SOUTHERN (Cardiff) wrote that a few years' experience as one of H.M. inspectors of mines had naturally

imbued him with a special interest in the prevention of accidents, and therefore he was glad that Mr. McLaren had brought the subject before the members in the paper in which he had so clearly put the results of his research. This subject was very important and had not received sufficient systematized attention hitherto. Perhaps that was due to the fact that it was a somewhat dry subject, involving many statistics; and Mr. McLaren's paper although a short one, showed that he must have devoted much time, thought and patient investigation to prepare so orderly and easily-followed a statement of the case.

He considered that Mr. McLaren had adopted a proper basis, and had not exaggerated his case; but, if anything, had understated it, as regards the accidents that he had classified as "preventible." And, although, in such a case one enquirer must inevitably have included some accidents which another enquirer would have left out, and *vice versa*, it seemed to him that this paper, as a whole, put forward a reasonable statement of the facts. Of course such causes as want of care, breaches of rules, and errors of judgment, are themselves not wholly preventible. Such causes will undoubtedly exist so long as the world lasts, but, as these accidents may rightly be described individually as preventible, they may, at the least, be described collectively as reducible. It is obviously a cause for general encouragement towards still greater exertions and precautions for the prevention of accidents, when we are shewn by Mr. McLaren, without exaggeration, that so large a proportion as 37 per cent. of the deaths from accidents in the coal-mines of the United Kingdom within the last three years can be justly considered to have been reasonably and practicably preventible, if, in each case, the "someone who blundered" had, as a result of better knowledge or better discipline or closer supervision, been saved from blundering.

Mr. McLaren had shewn that, notwithstanding the great advances which had been made during the last 30 years in attaining greater safety in coal-mines, there is still room for further improvement. Of course, even if there was not this direct cause for encouragement, and even if perfection could possibly be attained, "forward!" must always be the watchword, for any relaxation of discipline and precautions would inevitably bring about an increase in the number of accidents. There is certainly much ground for congratulation in the progress already achieved,

the comparatively excellent discipline and vigilant supervision, and the unsparing expenditure incurred in our mines in general for the prevention of accidents. All this is not by any means directed exclusively, or even chiefly, to the prevention of accidents which would endanger the workmen collectively, and over which the workman endangered has himself no control, but is equally, in fact mainly, directed to safeguard the workmen themselves, from accidents resulting from their own neglect or lack of knowledge and skill, and which would endanger only themselves, and from causes which they themselves can prevent or avoid.

He should like to support Mr. McLaren's suggestions by stating that, in his opinion, one very desirable step forward would be an attempt to bring about a decided improvement in the Special Rules. A comparison of the Special Rules of the various mines-inspection districts shews that some of the districts have a very inferior set of Special Rules as compared with those which are found perfectly practicable, and result in producing much better discipline, in some other districts. Even amongst those districts which have a good set of Special Rules, there are, in each district, a few excellent rules in force for ensuring safety, which would be equally appropriate to the conditions of work in other districts, but which are not in force there. In illustration of this remark, he would quote two instances from the Special Rules of the Midland mines-inspection district:—

Rule 79.—Any person taking a tub down an incline roadway by hand shall go behind it, and shall use sufficient scotches or other means of stopping the tub on the way, if required.

Rule 71.—No person shall withdraw, or attempt to withdraw, from out of any waste or from under any heavy roof any timber in use for supporting the roof, except by means of a ringer-and-chain.

These two rules deal with two fruitful causes of accident: they are in force and are found practicable in every coal-mine in the Midland mines-inspection district. Yet one may step across the border of the same coal-field, where the conditions are practically the same, and find that these rules are not in force and that the dangerous practices which they provide against may be in full swing, but cannot be repressed by legal authority, as their prohibition is not set down in black and white. In other words, the discipline and good management of the mines in one district do not profit so much and so directly as should be the case, from the combined study and experience derivable

from the working of mines throughout the country. He therefore suggested that the time had arrived when H.M. inspectors of mines, in collaboration amongst themselves and with mine-owners and colliery-managers, having due regard to the different customs existing in the working and management of mines in the various mines-inspection districts, should, as far as possible, introduce into the Special Rules of every district to which they are appropriate, all such rules as those he had indicated and which as yet are perhaps in force in only one or two districts. It is often said that the main purpose of Mines Regulation Acts is simply to bring the retrograde collieries into line with the best managed ones, and now he would advocate bringing the retrograde mines-inspection districts into line with those in which the best discipline prevails.

There is not the least doubt that many valuable lessons are to be derived from a study of the accidents recorded in the reports of H.M. inspectors of mines, but these reports are to a very great extent utterly useless as a means of educating under-officials and workmen. We commonly see at railway-stations a notice to the effect that on such a date a person (who is perhaps pilloried by name) was fined £2 and costs, for travelling without a ticket. Here is a warning published on a matter which no member of the public is likely to be ignorant about, or not to have thought of, or to forget, and sometimes there may be seen in a railway-station a printed notice giving a long list of such prosecutions. Would it not be at least equally reasonable, and he thought much more so, to suggest that notices might quarterly or monthly be published at collieries, by posting them on the pit-bank and also distributing a copy to each official, giving a condensed summary of the fatal and non-fatal accidents reported from various causes for the whole country during the previous month or quarter, and giving a brief description of any accident which had any noteworthy or specially important features connected with it, and also arranging the accidents recorded under headings shewing the class of workmen or branch of work which they concern, so that any workman or official can readily put his finger upon the information which is of most interest to himself? He did not mean that these notices should be extended by unnecessary details giving an endless repetition of the same cause of accident; but the publication might well be

confined exclusively to those accidents which, in the opinion of H.M. inspectors of mines, could be classed as "preventible colliery accidents" arising from breaches of rule, incurring of unnecessary risk, error of judgment, or neglect of reasonable care. He did not suggest in any case that dates or names of persons should be mentioned. Such periodical notices as these would naturally find their way into the mining newspapers, and it would be agreed that their publication might be productive of great benefit.*

Mr. A. B. MARKHAM, M.P. (Mansfield), remarked that he should like to say a few words respecting an accident at a colliery with which he was connected. A motor of 2 horsepower was driving a small fan which ventilated a short length of heading, and in the same pit he had two electrically-driven coal-cutting machines, and the men frequently complained of receiving shocks. The electric current had a pressure of 400 volts. He had the motors taken out of the pit and carefully examined, but without result. He came to the conclusion that continual vibration had some effect on the insulation of the field-coils, and that the current escaped from the coal-cutting machine to the rails. He had tried enclosing the motors in indiarubber, and he supplied the workmen with indiarubber gloves, but they still received shocks. A workman died after receiving a shock from a current of 400 volts. He had never heard of a similar case: he had himself received shocks of 400 volts through his system, and they had not done him any harm. If, however, a man died from a shock of 400 volts, and they were working coal-cutting machinery using 500 volts, they should consider how such dangers could be obviated.

* The Home Office has recently kindly furnished the writer with particulars of the publication of the reports of H.M. inspectors of mines for the three years, 1897, 1898 and 1899, from which it appears that 1,000 copies were printed of each of the *Annual Reports*. Nearly one-half of these were "issued to Parliament," viz., from 454 to 485 copies, and probably the bulk of these were promptly consigned to the waste-paper basket. From 82 to 152 copies (and in one case—the South-Western district—252 copies) were "issued to inspectors;" and from 248 to 286 copies (and, in one case, 430 copies) were "issued for sale," but what number of these copies were actually sold is not stated. Even on a liberal estimate, the number of copies distributed amongst colliery officials cannot have exceeded 500 copies of each annual report. Four special reports were published in the three years named, and the number of copies issued for sale were as follows:—Devon colliery, dam burst, 166; Drumpellier colliery, 193; Whitwick colliery, underground fire, 452; and Llest colliery, explosion, 216. Copies of these special reports were not distributed through H.M. inspectors of mines; and the copies issued for sale, as above stated, are the only copies distributed, beyond those issued to Parliament and 25 copies to H.M. inspector of mines for the district in which the accident occurred. As there are over 3,000 collieries in the United Kingdom, employing about 600,000 persons, these figures bear out the writer's remarks as to the utterly inadequate publication of the reports of H.M inspectors of mines, whereby the valuable information contained in them is almost entirely lost.

Mr. W. B. M. Jackson (Clay Cross) said that at Clay Cross similar difficulties had occurred from shocks, but not to the same extent as described by Mr. Markham. Occasionally, when a motor was out of order, a workman received a shock. As a preventive, the workmen had been supplied with indiarubber gloves, but they were inclined to neglect making use of them. The electric current had a pressure of 450 volts at the generator, and from 400 to 420 volts at the coal-cutting machines.

Mr. W. Price Abell (Derby) asked Mr. Jackson and Mr. Markham to describe the respective conditions of their mines with regard to moisture, in which the electric machines referred to were working. As a matter of fact, if one mine was wet and the other dry, this difference would account for the varying leakages and the varying susceptibility of the men to receive shocks, and the damp or sweaty man would be more likely to receive shocks than the dry or non-sweaty man.

Mr. G. E. Smith (Nottingham) said that one person would complain of a shock being painful, while another receiving the same current would not know whether he had touched it or not. He believed that it was possible for less than 400 volts to kill a man, but he had known men who could withstand much higher pressures. It was impossible to say what any particular man would stand, without a series of experiments upon the man. No single experiment would enable any reliable conclusion to be drawn. He had frequently to charge small cells for miners' lamps and other purposes, and he usually took them into a wooden shed, with a stone floor laid on the ground. He often received shocks, especially when his hands had been in contact with the liquid in the cells, but much depended on the sensitiveness of the subject, whether the boots were thin and damp, and whether the hands and feet were moist. Under such conditions, the shocks were always greater; and if, as sometimes happened, the hands were wetted with dilute sulphuric acid, the shock was more readily felt than when the hands were in the ordinary state of dryness.

Mr. A. H. Stokes said that electricity was a convenient motive power in mines, if it were kept under control. The arms and hands of a man doing his duty in a mine were usually damp. The workman mentioned by Mr. Markham had been employed in erecting signal-wires, and consequently he was

not absolutely ignorant as to the effects of electricity. He (Mr. Stokes) saw the man when he was dead, and he was, physically, well-built, well-nourished and in the prime of life. The primary cause of death was quite evident, as the marks of the two terminals were burnt into his right arm. The man had been trying to screw a nut on to the motor, and he had caught his arms on the terminals, which held him fast. He called out, and a man near by ran to the double-pole switch, and threw it out, cutting off the current. The pressure of the electric current could not have exceeded 450 volts, for it was cut out on the pit-bank at 500 volts, and the pit-bank was 1½ miles distant. In this case, the nearest workman ran for help, but when he came back the man had succumbed. The proper remedy in such cases was to start immediately artificial respiration, after setting the person free from the electric current. The current seemed to affect the muscles of the lungs, so that no blood flowed from the heart, and no air could enter the lungs. The muscular contraction caused by the electric current expelled the air from the lungs, and did not allow them to expand again. Artificial respiration was therefore essential, and should be continued until they were assured that the man was truly dead. If it had been tried in the Wyken case, possibly the man's life would have been saved.

Mr. G. E. Smith asked whether the leakage to earth of the ventilating-motor had been tested. If the current had passed through his arm from terminal to terminal, there must have been an earth-current, or his lungs would not have been affected.

Mr. E. Lindley (Eastwood) said that, as a member of the Nottingham County Council Technical Education Committee, he firmly believed that their lectures on mining had been very beneficial as regarded the prevention of accidents, and instruction of a practical character had been given with this object.

Dr. W. H. Gray (Mansfield) said that at one colliery he took 100 consecutive cases, and he found that injuries to the hand and fingers were in proportion greatly in excess of those to any other part of the body, being in fact 33 per cent. The duration of incapacity or the time which elapsed before they returned to work was, in this particular class of accidents, over 4 weeks, and he thought that it might be due, in great part, to

the wounds not receiving proper attention in the first instance. Supposing that a wound was not properly treated, and a piece of sticking-plaster used to protect it, some dirt, or the germs of disease might cause a septic inflammation, popularly known as blood-poisoning. Blood-poisoning was preventible, and if a wound were properly cleansed with soap and water, and afterwards with an antiseptic fluid, it would be possible to considerably reduce this time of incapacity. The treatment, to be of any use, and to be effectual, ought to be undertaken as soon as possible after the accident had happened. It was too late to wash out wounds 24 hours afterwards. If it were possible to attend to the wound before the man left the pit the best result would be obtained. Briefly, a wound should first be washed to remove the superficial dirt, next thoroughly bathed with an antiseptic fluid, and finally covered with a piece of lint and a bandage. The man should immediately afterwards be sent home, and told to go to his doctor as soon as possible.

The PRESIDENT (Mr. M. Deacon) said that he was extremely doubtful whether technical education was going to reduce materially the number of accidents in mines; but he had no doubt that a liberal education, whether technical or not, must develop the intelligence of the individual; and that was what they wanted, in order to reduce accidents. Men should be taught to pay rigid attention to the dangers which existed, and to be less impervious to the perils which were constantly present; and that would be achieved to some extent by a higher class of education. In his opinion, the most important and the most practical means for the prevention of accidents was the exercise of rigid discipline, especially on the part of deputies and under-managers. The discipline established by colliery-managers was, as a rule almost perfect, but he had to encounter the difficulty of ensuring that his under-officials exercised careful attention, energy, and determination in carrying out his instructions. At the same time, he thought, if greater attention were paid by the colliery-manager to the exercise by the deputies of the powers placed in their hands, that fewer accidents would occur. He usually found many things which ought not to be in pits, and in nine cases out of ten, they could be traced to the laxity of the deputies.

Mr. McLaren had referred to 12 deaths having occurred from

riding on cranks, and 11 deaths from riding in empty tubs.* It was an open question whether those two methods of travelling were not the safest that could be adopted. He might be wrong, but if there had not been 23 deaths in that way, 46 deaths might have occurred by being crushed between the tub and the side or by being run over, and so on. Accidents caused by being crushed between railway-wagons and the columns of the screens, sometimes occurred at old plants, where sufficient care had not been taken to leave room for the shunters to pass between the wagons and the columns;† but, in new plants, care would be taken, in preparing the design, to prevent the occurrence of such accidents. The suggestion that a double set of safety-props should be placed in the head-gear, near to the safety detaching-hook plate,‡ might be applied in new designs, but it could not be applied to many existing head-stocks. In designing new head-gear, however, it was desirable to provide safety-props; it was scarcely possible that they would cause accidents, and they might prevent them. If a cage were drawn up above the pit-top at a high velocity, it would ascend, by its momentum, to the detaching-hook plate before it stopped and began to fall. The fall of the cage might break the bridle-chains, or the safety-hooks, and, in the absence of safety-props, the cage might cause a terrible accident. If strongly constructed safety-props were fitted, the accident might be prevented. He agreed with the desirability of Mr. McLaren's suggestion that safety-lamps should be used when making the first examination of the workings in collieries where naked lights are in use, or when testing for gas.§ Mr. McLaren pointed out that, on testing the wires of broken ropes, the tensile strain was high while the torsional strain was low; but similar results were obtained from ropes which had been at work whether they had broken or not. The torsional strength of the wires of a rope after 1 or 2 years' use would not be more than one-tenth of the torsional strength of the wires of a new rope. He (Mr. Deacon) therefore attached greater importance to the tensile strain than to the torsional strain, although the torsional strain gave an indication of the quality of the wires of the rope.

* *Trans. Inst. M.E.*, vol. xix., page 27.

† *Ibid.*, page 28.

‡ *Ibid.*, pages 26 and 31.

§ *Ibid.*, pages 23 and 30.

Careful attention should be paid to the suggestions contained in Messrs. McLaren and Farmer's papers, and if rigid discipline were enforced, the number of accidents would undoubtedly be reduced, and the labour of the two gentlemen who had written these valuable papers would not be wasted.

The further discussion was adjourned.

THE INSTITUTION OF MINING ENGINEERS.

ELEVENTH ANNUAL GENERAL MEETING,

HELD IN THE CROWN COURT, GUILDHALL, BRISTOL, SEPTEMBER 18TH, 1900.

MR. H. C. PEAKE, RETIRING-PRESIDENT, IN THE CHAIR.

The LORD MAYOR OF BRISTOL (Sir Herbert Ashman), in welcoming the members, trusted that the conference would prove of great service to the honourable profession which they represented, and that individually they would carry away from Bristol very pleasant recollections of the city and citizens. There was an appropriateness in visiting this city, as he understood it was in that western country that the first mining operations were made. Very long before the great coal-fields were discovered in the north, tin was exported from Cornwall, and lead was worked on the Mendips, and not only had they this ancient mining history, but they had now their iron industries—not great industries, perhaps, compared with those of the North of England, but the rich deposits of ore were capable of receiving, and soon, he hoped, would receive, energetic development. The great coal-field of South Wales was just beyond their borders, but within those borders were the coal-fields of Gloucestershire and Somerset. The Institution of Mining Engineers represented, he thought, their most important industry; for coal and iron were the barometers of the commercial world; and on the prosperity of these industries that of the nation largely depended. When coal and iron were depressed, commerce dragged heavily; and when they flourished all other industries flourished with them. He did not know whether, as Lord Mayor, he might presume to caution those whom he welcomed, but sometimes one had to accept responsibilities, and he could not help saying at this moment that there was a danger of coal becoming too dear. Playing as it did so important a part in the industries of the nation there was, perhaps, a danger of mine-proprietors

grasping at the immediate advantage, and as it were "killing the goose which laid the golden eggs," and forcing prices to a point at which manufacturing energy might be paralysed; and the result of such a course must, of course, be ultimate disaster. Already American steam-coal was competing with our own products, Japan threatened our Eastern markets, and Germany and Belgium were also in the market against us, and might become strong competitors. Prudence and caution were all that was necessary to continue that prosperity with which God had so blessed our nation. On behalf of the citizens of the ancient city of Bristol he extended to the members of The Institution of Mining Engineers a most cordial welcome.

The CHAIRMAN (Mr. H. C. Peake) acknowledged the indebtedness of the members of the Institution to the Lord Mayor, both for his very kindly welcome, and also for the permission to use the rooms in which the meeting was held. They were glad to be reminded of the ancient nature of the mining operations of the district. He agreed with his lordship that the price of coal should not be allowed to rise much higher. Mining engineers were at present looked upon with a certain amount of suspicion as being in collusion with colliery-owners to keep up the price of coal; but this was not so. The price of coal had for many years been very low, the profits had been insufficient to meet ordinary depreciation of the colliery and plant, there had been no inducement to invest money in the business; consequently there had not been that increased development which would have enabled the supply to keep pace with the demand; and except for the past depression, the present crisis would not have arisen to the same extent. Those who complained most bitterly of the rise in the price of coal were the chairmen of the gas and water companies, who for some years had retained all the profits which the coal-owner should have received, having been able to reduce the price of gas to a low figure, and taking advantage of their sliding-scales, they paid large dividends to their shareholders. Of course, there was not so much cheaply-worked coal to be got as formerly; the more easily-worked seams were being gradually exhausted, or had to be obtained from greater depths, and the cost of raising coal must inevitably increase with the exhaustion of the shallower and more cheaply-worked seams. There was immense room for economy in the use of fuel:

with appliances for household-consumption such as are in vogue in the northern countries of Europe or in America: houses might be kept warmer than now with one-tenth part of the fuel that is used. We were, however, very like the birds who build their nests in the same way now as all their ancestors have done—so conservative—that it was very unlikely that as long as any coal could be obtained, any change would be made. The economies which had been effected in the past 20 or 30 years in the cost of steamship propulsion—or rather the increased speed—were only the forerunners of what might be done in other trades. It might be asked why should he advocate economy, and how could that do good to the coal-owner? His reply was that over a series of years, as he had previously explained, money would not be invested in collieries unless an adequate return was made for the risk, and that in the long run the nation would benefit. He had pleasure in moving a vote of thanks to the Lord Mayor for his cordial reception.

Mr. T. Forster Brown (Bristol) in seconding the vote of thanks to the Lord Mayor for the gracious and happy way in which he had received the members, said it was quite true that mining was commenced at a very early period in this district, unfortunately, as they would see from the papers to be read, the coal-field was not adapted for a very large output, but it had the advantage that it would last longer than any other coal-field in Great Britain, and therefore, Bristol might look forward to a continuance of prosperity long after some of its competitors had vanished. The members would find many subjects of great interest, for its characteristics were very distinct from those of other districts. The Coal-measures were unusually thick, and an unusually thick stratum of barren measures prevented the Lower Coal-measures from being worked. A larger part of the coal-field was overlain with newer measures than was the case elsewhere, and these features ought to make the visit of the members to Bristol a most interesting one.

The motion was cordially adopted.

ELECTION OF OFFICERS, 1900-1901.

The SECRETARY announced the election of the following officers by the Council:—

PRESIDENT.

SIR W. T. LEWIS, Bart.

VICE-PRESIDENTS.

Mr. T. FORSTER BROWN.	Mr. M. DEACON.	Mr. W. D. HOLFORD.
Mr. JAMES C. CADMAN.	Mr. JAMES S. DIXON.	Mr. GEORGE MAY.
Mr. W. COCHRANE.	Mr. J. T. FORGIE.	Mr. F. N. WARDELL.
Mr. JOHN DAGLISH.	Mr. JOHN GERRARD.	Mr. J. G. WEEKS.
	Mr. R. S. WILLIAMSON.	

AUDITORS.

Messrs. JOHN G. BENSON AND SON, Newcastle-upon-Tyne.

TREASURERS.

Messrs. LAMBTON AND COMPANY, The Bank, Newcastle-upon-Tyne.

Mr. JAMES MCMURTIE moved that a hearty vote of thanks be accorded to Mr. H. C. Peake for his services as President of the Institution during the past year.

The resolution was carried by acclamation.

PRIZES.

The SECRETARY announced that the Council had awarded prizes of books to writers of the following papers, which had been published in volumes xvi. and xvii. of the *Transactions*:—

"Mechanical Ventilators." By Mr. M. Walton Brown.
"Colliery Consumption." By Mr. J. A. Longden.
"Observations on the Relation of Underground Temperature and Spontaneous Fires in the Coal to Oxidation, and to the Causes which favour it." By Dr. J. S. Haldane and Mr. F. G. Meachem.

The SECRETARY read the Annual Report of the Council as follows:—

ELEVENTH ANNUAL REPORT OF THE COUNCIL.

The Council are again able to congratulate the members upon the success that has attended The Institution of Mining Engineers during the year.

The federated societies continue the same, namely, the Chesterfield and Midland Counties Institution of Engineers; the Midland Institute of Mining, Civil and Mechanical Engineers; the Mining Institute of Scotland; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the South Staffordshire and East Worcestershire Institute of Mining Engineers.

The influence of the Institution would become more effective, and the value of the *Transactions* would be considerably enhanced, if it included other societies formed for the advancement of mining engineering, metallurgy and their allied industries. The Council would therefore urge members, who may be interested in other kindred societies, to use their influence in favour of federation with this Institution.

The objects of the Institution are well known, but the members can materially add to its prosperity by enhancing its advantages and increasing its membership. The members receive the *Transactions* containing the papers read at the meetings of the federated institutes, and, in addition, participate in the general meetings held in each year in the mining districts and in London.

Arrangements have been made enabling members to purchase for a small extra subscription, the *Transactions* of the four following societies: the Australasian Institute of Mining Engineers; the Canadian Mining Institute; the Institution of Mining and Metallurgy; and the Mining Society of Nova Scotia.

The register now includes 2,457 members and 35 non-federated members—a total of 2,482 names.

Two general meetings have been held during the year, namely, in South Yorkshire and in London; and the members were associated with the International Congress of Mining and Metallurgy held in Paris in June, 1900, when papers of considerable interest were communicated. The thanks of the Institution have been conveyed to the gentlemen who kindly allowed their works and collieries to be visited by the members

during the period of these meetings. The attendance of members at the general meetings has been satisfactory, notwithstanding the fact that they reside in all parts of the kingdom, the colonies, and abroad.

Presidential addresses have been delivered during the year to the members of The Institution of Mining Engineers by Mr. H. C. Peake; the Chesterfield and Midland Counties Institution of Engineers by Mr. Maurice Deacon; and the North Staffordshire Institute of Mining and Mechanical Engineers by Mr. J. C. Cadman.

The papers on geology include the following:—

"The Probable Duration of the Scottish Coal fields." By Mr. Robert W. Dron.

"Preliminary Study of Recent Borings made in the North of France in search of the Coal-basin." By Prof. J. Gosselet.

"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse.

"The Coal-fields of Natal." By Mr. Wm. Taylor Heslop.

"The Devonian Iron-ores of Asturias, Spain." By Mr. J. A. Jones.

"Geology of the Coromandel Gold-fields, New Zealand." By Mr. J. Malcolm Maclaren.

"Mining District near Kamloops Lake, British Columbia." By Mr. G. F. Monckton.

"Ore-deposits of Mount Lyell, Tasmania." By Mr. J. J. Muir.

"The Portuguese Manica Gold-field." By Mr. A. R. Sawyer.

"Castleton: History, Geology, Minerals and Mining." By Mr. A. H. Stokes.

"Underground Geology in the South-east of England." By Mr. W. Whitaker.

Mining engineering and safety-appliances have been discussed in the following papers:—

"The Balmer Pit-prop."

"The Driving of a Stone-drift at the West Wylam Collieries." By Mr. Sydney Bates.

"The Kalgoorlie Gold-field." By Mr. S. J. Becher.

"An Indian Colliery and its Miners." By Mr. Henry M. Cadell.

"Description of Present and Proposed Methods of Operating Vinton No. 3 Colliery, Vintondale, Pennsylvania, U.S.A." By Mr. Clarence R. Claghorn.

"Notes on Hamilton Palace Colliery." By Mr. James S. Dixon.

"Mining in the Southern Klerksdorp Gold-fields, Western Transvaal." By Mr. Joseph Hassall.

"The Hepplewhite Tapered Pit-props and Bars." By Mr. Wm. Hutton Hepplewhite.

"Description of the Sinking of Two Shafts through heavily-watered Strata at Maypole Colliery, Abram, near Wigan." By Mr. James Keen.

"An Ordinary Miner's Boring-machine adapted for Boring against Wastes." By Mr. Robert Martin.

"The Klondyke Gold-fields." By Mr. John Meiklejohn.
"The Witwatersrand Gold-fields." By Mr. Francis Olds.
"The Gold-mines of Boulder County, Colorado, U.S.A." By Mr. Frank Owen.
"The Mineral Resources of Tasmania." By Mr. John J. Sandeman.
"Longwall Methods in the Eastwood District, Nottinghamshire." By Mr. Norman M. Thornton.
"The Subsidences in and around the Town of Northwich in Cheshire." By Mr. Thomas Ward.

Mechanical engineering has been the subject of the following papers:—

"An Electric Pump for Underground Use." By Mr. Emerson Bainbridge.
"Compound Cornish Pumping-engines." By Mr. Henry Davey.
"Economy in Steam-engine Practice." By Prof. John Goodman.
"Notes on the Kœpe System of Winding." By Messrs. John Gregory and John T. Stobbs.
"Endless-rope Haulage at Lethbridge Colliery." By Mr. Wm. D. L. Hardie.
"Underground Haulage at Glapwell Colliery." By Mr. J. F. Lee.
"The Ljungström Crankless Engine."
"A Power-indicator for Steam-engines." By Mr. W. Ripper.
"Hauling and Pumping Underground by an Oil-engine." By Mr. William Smith.
"Hydraulic Cage-loading and Unloading Apparatus at Cadeby Colliery." By Mr. G. B. Stones.

The following papers have been contributed on mine-ventilation, safety-lamps, coal-dust, colliery explosions, etc.:—

"Instantaneous Outbursts of Fire-damp and Coal, Broad Oak Colliery." By Mr. John Gerrard.
"Automatic Sprayer for Preventing accumulations of Dust in Mines." By Mr. R. Harle.
"Report of the Committee of the Midland Institute of Mining, Civil and Mechanical Engineers upon Recovery Stations."
"Explosions of Fire-damp and Coal-dust in the West of Scotland." By Mr. Thomas H. Mottram.
"New Ventilating Fan." By Mr. R. Oswald.
"The Howat Safety-lamp." By Mr. J. G. Patterson.

A use for liquid air as an explosive is described in the following paper:—

"Liquid Air, and its Use as an Explosive." By Mr. Axel Larsen.

The following papers have been written on coal-cutting machinery:—

"An American Longwall Mining Machine." By Mr. H. Foster Bain.
"Coal-cutting Machinery." By Mr. Henry Davis.

The rating of coal-mines has been discussed in the following papers:—

"The Rating of Coal-mines." By Mr. George Humphreys-Davies.
"The Rating of Coal-mines." By Mr. Alexander Smith.

The subject of preventible accidents is discussed in the following papers:—

"Mining Accidents and their Prevention." By Mr. George Farmer.
"Preventible Colliery Fatalities." By Mr. B. McLaren.

The methods of extinguishing mine-fires are described in the following papers:—

"Notes on Gob-fires." By Mr. W. H. Chambers.
"The Hamstead Colliery Fire." By Mr. Fred. G. Meacham.

Instruments for mine-surveying are described in the following papers:—

"Notes upon Ancient and Modern Surveying, and Surveying Instruments, Books, Tables, etc." By Mr. H. D. Hoskold.
"Underground Surveys and their Connexion with the Surface by the Transit Method." By Prof. E. H. Liveing.

The miscellaneous papers include:—

"Report of the Delegate of the Mining Institute of Scotland to the Conference of Delegates of Corresponding Societies of the British Association for the Advancement of Science, Dover, September, 1899." By Mr. James Barrowman.
"Barometer, Thermometer, etc., Readings for the Year 1899. By Mr. M. Walton Brown.
"Description of a Plant of Semet-Solvay Bye-product Coke-ovens at Wheeling, West Virginia, U.S.A." By Mr. W. H. Blauvelt.
"Dover Harbour Works." By Messrs J. C. Coode and W. Matthews.
"Observations on Sampling, Computation of Assay-averages, and Relation of Assay-value to Recovery-value, as applied to Banket-mining in the Transvaal." By Mr. G. A. Denny.
"Practical Application of the Process for the Production of High Temperatures by the Combustion of Aluminium." By Dr. Hans Goldschmidt.
"Dock Equipment for the Rapid Handling of Coal and Ore on the Great American Lakes." By Mr. Arthur C. Johnston.
"Conference of Delegates of Corresponding Societies of the British Association for the Advancement of Science, Bristol, 1898." By Prof. Henry Louis.
"The Feeding of Horses, with Special Reference to Colliery Studs." By Mr. F. O. Solomon.

The foregoing lists demonstrate the varied nature of the papers (66) communicated during the year, and printed in the *Transactions* (vols. xviii. and xix.), and the Council venture to

hope that members will continue to send in papers as liberally as heretofore.

"Notes of Papers (183) on the Working of Mines, Metallurgy, etc., from the Transactions of Colonial and Foreign Societies and Colonial and Foreign Publications" have been continued, and should prove of value to the members.

Messrs. J. S. Martin and J. Batey represented the Institution at the Southampton meeting of the Sanitary Institute, in August, 1899; and Prof. H. Louis on the Corresponding Societies Committee of the British Association for the Advancement of Science at Dover in September, 1899.

The Copyright Bill [295] recently under discussion in the House of Lords ignores the publications of societies, which, as a rule, do not pay their contributors; and it does not provide for the copyright of their *Transactions*. The Council recommend that the following amendment be inserted in clause 10: "The copyright of all articles contributed to and accepted by a literary or scientific society or institution and printed within 12 months shall, unless it be otherwise agreed between the contributor and the institution, be vested in the society or institution." The members will recognize that the proposed amendment is based upon the existing rules of this and many other societies. An amendment has been inserted in the Bill, at the suggestion of this Institution, providing that "copyright shall not be infringed by a person making an abridgment . . . . in the ordinary course of reporting scientific information," such as the abstracts of foreign and colonial publications appearing in the *Transactions*.

The onerous cost of postage of the *Transactions*, as compared with that of daily and weekly publications has been considered. The following question was recently asked in the House of Commons, by Mr. Emerson Bainbridge, M.P.:—Whether, in view of the fact that the periodic journals of scientific societies do not enjoy the same postal rates as are granted to weekly publications registered as newspapers (the cost incurred in postage on the former being a tax on the dissemination of valuable and useful knowledge by scientific societies, and detrimental to the advancement of scientific industries), the Postmaster General will consider the advisability of arranging that the postage on publications of scientific societies shall be at the same rates as are in force for registered newspapers? Mr. Hanbury, Financial Secretary to the

Dr. THE TREASURER IN ACCOUNT WITH
FOR THE YEAR

July 31, 1899.	£ s. d.	£ s. d
To Balance at Bank	1,063 14 8	
„ „ in Secretary's hands	22 18 10	
		1,086 13 6
To Subscriptions for year ending July 31, 1899—		
Federated—		
Chesterfield and Midland Counties Institution of Engineers	£51 6 0	
Midland Institute of Mining, Civil and Mechanical Engineers	5 14 0	
Mining Institute of Scotland	0 19 0	
North of England Institute of Mining and Mechanical Engineers	63 13 0	
North Staffordshire Institute of Mining and Mechanical Engineers	13 5 11	
South Staffordshire and East Worcestershire Institute of Mining Engineers	21 17 0	
		156 14 11
To Subscriptions for year ending July 31, 1900—		
Federated—		
Chesterfield and Midland Counties Institution of Engineers	£266 0 0	
Midland Institute of Mining, Civil and Mechanical Engineers	247 19 0	
Mining Institute of Scotland	370 13 6	
North of England Institute of Mining and Mechanical Engineers	1,072 11 0	
North Staffordshire Institute of Mining and Mechanical Engineers	113 1 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	55 2 0	
		2,125 6 6
Non-Federated—		
Mining Institute of Scotland		17 10 0
Carried forward		£3,386 4 11

THE INSTITUTION OF MINING ENGINEERS. Cr.
ENDING JULY 31, 1900.

July 31, 1900.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
By Printing—				
Transactions, Vol. XVI., plates	7 15 0			
„ „ „ printing	105 5 0			
		113 0 0		
„ „ XVII., printing	506 16 9			
„ „ „ plates	227 6 6			
		734 3 3		
„ „ XVIII., printing	326 14 6			
„ „ „ plates	129 12 6			
		456 7 0		
„ „ XIX., plates	3 13 1			
		3 13 1		
			1,307 3 4	
Excerpts, Vol. XVII.		100 10 2		
„ „ XVIII.		29 8 4		
			129 18 6	
Proofs of Papers for General Meetings		.....	10 6 4	
Circulars		.....	24 2 11	
				1,471 11 1
By Addressing *Transactions*		.....	27 17 0	
„ Postages—Circulars		16 10 8		
„ „ Correspondence		20 2 9		
„ „ *Transactions*		232 5 4		
			268 18 9	
„ Stationery, etc.		.....	44 5 7	
„ Insurance of *Transactions*		.....	3 0 0	
„ Binding—Library		4 4 6		
„ „ Sundries		4 6 10		
„ „ *Transactions*		27 0 3		
			35 11 7	
„ Reporting General Meetings		.....	16 12 5	
„ Expenses of General Meetings		.....	4 6 10	
„ Petty Cash		.....	6 13 9	
„ Incidental Expenses		.....	7 9 11	
„ Salaries, Wages, Auditor, etc., ...		.....	529 11 3	
„ Indexing *Transactions*		.....	22 19 0	
„ Travelling Expenses		.....	44 6 10	
				1,011 12 9
„ Advertizement—Commission		83 14 0		
„ „ Printing		1 14 6		
			85 8 6	
				85 8 6
„ Translations of Papers		.....	9 10 0	
„ Abstracts of Foreign Papers, Vol. XVII.		.....	22 7 9	
„ Barometer Readings, etc.		.....	6 13 0	
„ Calendars		.....	14 3 6	
„ Mechanical Ventilators Committee		.....	8 10 0	
„ Stock-rooms, etc., ...		.....	9 3 7	
„ Typewriter		.....	15 7 0	
				85 14 10
Carried forward				£2,654 7 2

Dr. THE TREASURER IN ACCOUNT WITH

	£ s. d.	£ s. d.	£ s. d.
Brought forward			3,386 4 11
To Local Publications and Authors' Copies—	1898-99.	1899-1900.	
The Institution of Mining Engineers... ...	0 0 0	27 13 4	
Chesterfield and Midland Counties Institution of Engineers	0 0 0	2 1 3	
Midland Institute of Mining, Civil and Mechanical Engineers	0 0 0	14 6 9	
Mining Institute of Scotland	0 0 0	7 7 10	
North of England Institute of Mining and Mechanical Engineers	0 0 0	24 2 6	
North Staffordshire Institute of Mining and Mechanical Engineers	0 15 9	6 14 1	
South Staffordshire and East Worcestershire Institute of Mining Engineers	0 19 2	0 0 0	
	1 14 11	82 5 9	84 0 8
To Sales of Transactions, etc.—	1898-99.	1899-1900.	
Members and others	1 8 6	132 11 7	
Chesterfield and Midland Counties Institution of Engineers	6 16 8	17 16 8	
Midland Institute of Mining, Civil and Mechanical Engineers	0 0 0	2 16 8	
Mining Institute of Scotland	0 13 4	2 16 8	
North of England Institute of Mining and Mechanical Engineers	1 0 0	10 4 8	
North Staffordshire Institute of Mining and Mechanical Engineers	5 13 4	3 16 8	
South Staffordshire and East Worcestershire Institute of Mining Engineers	11 13 4	0 0 0	
	27 5 2	170 2 11	197 8 1
To Reducing Plates—	1898-99.	1899-1900.	
Chesterfield and Midland Counties Institution of Engineers	0 0 0	0 0 0	
Midland Institute of Mining, Civil and Mechanical Engineers	0 10 0	0 0 0	
Mining Institute of Scotland	1 0 0	0 0 0	
North of England Institute of Mining and Mechanical Engineers	0 0 0	0 0 0	
North Staffordshire Institute of Mining and Mechanical Engineers	0 0 0	0 0 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	0 10 0	0 0 0	
	2 0 0	0 0 0	2 0 0
To Advertizements			334 16 1
To Address Labels			5 17 6
			£4,010 7 3

THE INSTITUTION OF MINING ENGINEERS.—*Continued.* Cr.

				£	s.	d.
	Brought forward			2,654	7	2
By	Mining Institute of Scotland—Amount refunded for Excerpts			10	0	7
,,	Balance at Bank	1,168	11 6			
,,	,, in Secretary's hands	177	8 0			
				1,345	19	6
				£4,010	7	3

We have examined the above account of receipts and payments, with the books and vouchers relating thereto, and certify that in our opinion it is correct.

JOHN G. BENSON & SON,
Chartered Accountants.

Newcastle-upon-Tyne,
August 31st, 1900.

THE INSTITUTION OF
BALANCE SHEET.—

Liabilities.

	£ s. d.	£ s. d.
Sundry Creditors—		
Advertizements Paid in Advance	31 16 8	
Printing, etc.	1,080 0 0	
Postage of Transactions	270 0 0	
Abstracts of Foreign Papers, Volumes XVIII. and XIX.	136 16 8	
Barometer Readings	8 0 0	
Prizes for Papers in Volumes XVI., XVII., XVIII., and XIX.	40 0 0	
Index, Volumes XVIII. and XIX.	30 0 0	
Advertizement Commission, etc.	62 10 8	
		1,659 4 0
Balance of Assets over Liabilities		931 11 1

We have examined the above Balance Sheet, with the books and vouchers relating thereto, and certify that in our opinion it exhibits a correct view of the affairs of the Institution.

We have accepted the asset "Transactions in Stock" as valued by the Officials of the Institution.

JOHN G. BENSON & SON,
Chartered Accountants.

Newcastle-upon-Tyne,
April 15th, 1901.

£2,590 15 1

MINING ENGINEERS.
JULY 31, 1900.

Assets.

	£ s. d.	£ s. d
Balance at Bank	1,168 11 6	
,, in hand	177 8 0	
		1,345 19 6
Subscriptions for Year ending July 31, 1900, Unpaid—		
Federated—		
Chesterfield and Midland Counties Institution of Engineers	27 11 0	
Midland Institute of Mining, Civil and Mechanical Engineers	1 18 0	
Mining Institute of Scotland	3 12 6	
North of England Institute of Mining and Mechanical Engineers	67 9 0	
North Staffordshire Institute of Mining and Mechanical Engineers	34 4 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	50 7 0	
		185 1 6
Local Publications and Authors' Copies, Unpaid—		
Midland Institute of Mining, Civil and Mechanical Engineers	0 11 0	
		0 11 0
Transactions Sold, Unpaid—		
The Institution of Mining Engineers	1 2 0	
Chesterfield and Midland Counties Institution of Engineers	5 0 0	
North of England Institute of Mining and Mechanical Engineers	1 0 0	
North Staffordshire Institute of Mining and Mechanical Engineers	3 0 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	3 16 8	
		13 18 8
Reducing Plates, Unpaid—		
Chesterfield and Midland Counties Institution of Engineers	2 10 0	
Midland Institute of Mining, Civil and Mechanical Engineers	3 10 0	
Mining Institute of Scotland	2 10 0	
North of England Institute of Mining and Mechanical Engineers	4 0 0	
North Staffordshire Institute of Mining and Mechanical Engineers	1 0 0	
		13 10 0
Advertizements, Unpaid		281 19 5
		1,841 0 1
Transactions in Stock		749 15 0
		£2,590 15 1

BOOKS, Etc., ADDED TO THE LIBRARY.

African Review, Nos. 357-407.

Annales des Mines de Belgique, vol. iv., No. 4; and vol. v., Nos. 1-3.

Australasian Institute of Mining Engineers, Transactions, vol. vi.

Australian Mining Standard, Nos. 550, 553, 554, 557, 558 and 561-609.

British Association for the Advancement of Science, Report of the Sixty-ninth Meeting, held at Dover, in September, 1899, demy octavo, cxxiv., 959 and 112 pages.

British Society of Mining Students, Journal, vol. xxii., Nos. 2-6 and Index; vol. xxiii., No. 1; and Index to vols. i.-xx.

Canadian Mining Institute, Journal, vol. iii.

Chemical and Metallurgical Society of South Africa, Journal, vol. ii., No. 8.

Coal and Iron, Nos. 192-217.

Colliery Hand-book for the Counties of Yorkshire, Derbyshire, Nottinghamshire, Leicestershire and Warwickshire. Containing Maps of the Railways and Collieries. Edited by F. W. Hardwick. Demy octavo, 348 pages.

Cory Brothers, British Coal Trade and Freight Circular, September 30th, 1899, to July 31st, 1900.

Engineering and Mining Journal, vol. lxviii., Nos. 12-27; vol. lxix., Nos. 1-26; and vol. lxx., Nos. 1-9.

Engineering Times, vol. i., Nos. 1-3; vol. ii., Nos. 3-6; vol. iii., Nos. 1-5; and vol. iv., Nos. 1 and 2.

Franklin Institute of the State of Pennsylvania, U.S.A., Journal, vol. cxlviii., Nos. 4-6; vol. cxlix., Nos. 1-6; and vol. cl., Nos. 1-3.

Geological Institution of the University of Upsala, Bulletin, vol. i., Nos. 1 and 2; vol. ii., Nos. 3 and 4; vol. iii., Nos. 5 and 6; and vol. iv., Nos. 7 and 8.

Institution of Mining and Metallurgy, Transactions, vol. vii.

Lake Superior Mining Institute, Proceedings, vol. v.

Manchester Geological Society, Transactions, vol. xxvi., Nos. 7-16.

Massachussets Institute of Technology, Technology Quarterly, vol. xii., Nos. 3 and 4; and vol. xiii., Nos. 1 and 2.

Mining Society of Nova Scotia, Journal, vols. iv. and v.

New South Wales, Department of Mines, Annual Report, 1898.

———, Geological Survey, Mineral Resources, Nos. 6 and 7.

Queensland, Annual Report of the Under-Secretary for Mines to the Honourable Robert Philp, Secretary for Mines, including the Reports of the Wardens, Inspectors of Mines, Government Geologist, Government Analyst, and other Reports, for 1899. Foolscap folio, 201 pages.

—, Report on the Geology of the West Moreton or Ipswich Coal-fields, by Walter E. Cameron, Government Geologist; also Queensland Coal: its Economic Value as a Steam Coal, a paper read before the Queensland Institute of Mechanical Engineers, December, 1892, by Robert Wilson. Foolscap folio, 29 pages and 3 plates. 1899.

South Wales Institute of Engineers, Transactions, vol. xxi., Nos. 5-8.

Victoria, Chamber of Mines, Melbourne. The Gold-Fields of Victoria, Monthly Returns, April to June, 1900.

—, Department of Mines, Geological Survey of Victoria, Monthly Progress Reports, Nos. 1 (April, 1899) -10 (January, 1900).

Western Australia, Department of Mines, Annual Report, 1898.

——, ———, Gold Mining Statistics, 1898.

EXCHANGES.

Annales des Mines de Belgique.
Australasian Institute of Mining Engineers.
British Association for the Advancement of Science.
British Society of Mining Students.
Canadian Mining Institute.
Chemical and Metallurgical Society of South Africa.
Franklin Institute of the State of Pennsylvania, U.S.A.
Geological Institution of the University of Upsala, Sweden.
*Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
Lake Superior Mining Institute.
Manchester Geological Society.
Massachussets Institute of Technology.
Mining Society of Nova Scotia, Canada.
New South Wales, Department of Mines and Agriculture, Geological Survey.
*New Zealand Institute of Mining Engineers.
*Revue Universelle des Mines, de la Métallurgie, etc.
South Wales Institute of Engineers.
*Transvaal, Department of the Mining Commissioner.

*No publications received during current year.

July 31st, 1900.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, BRADFORD, 1900.

The Report of the Delegate (Prof. H. Louis) representing the Institution was read as follows:—

NEWCASTLE-UPON-TYNE,
September 14th, 1900.

TO THE PRESIDENT AND COUNCIL OF THE INSTITUTION OF MINING ENGINEERS.

GENTLEMEN,

I beg to report that I attended the meeting of the British Association for the Advancement of Science at Bradford as your delegate.

As usual, two Conferences of the Delegates of Corresponding Societies were held, on September 6th and 11th respectively, both of which I attended. At the former, the resolutions submitted by the Yorkshire Naturalists' Union, relative to the mode of conducting the Conferences, were brought forward and discussed at length. I had been instructed by you to support these resolutions, and did so, but they were never put formally to the meeting. It was generally admitted on all sides that the Conferences, as at present conducted, were of but little value to the Corresponding Societies, and it was suggested that the fault lay largely with the societies themselves, in that they did not propose subjects of general interest suitable for discussion at these Conferences.

A motion was then submitted by Mr. M. Walton Brown, and seconded by Mr. Eli Sowerbutts, to the effect that the Council of the British Association be requested, through the Committee of Recommendations, to take proper steps for the protection of the Corresponding Societies in the matter of securing their copyright in their publications. I strongly supported this resolution, which was carried unanimously. I attended the meeting of the General Committee on September 12th, when the report of the Committee of Recommendations was received ; to my surprise, no reference was made to this matter of copyright, and, on enquiring of one of the General Secretaries, I was informed that the resolution had never been sent up from the Conference of Delegates. I had been unable at the second Conference, on September 11th, to ascertain that this resolution had not been duly sent up, because no minutes of the proceedings of those Conferences are kept. I have thought it advisable to report on this matter fully, because the copyright question is one of serious importance to this Institution, in common with other scientific societies. It is also obvious that the unbusinesslike mode of conducting these Conferences renders it hopeless to expect any results of real utility to the Corresponding Societies, and the practice of dispensing with a minute-book, however convenient it may be for covering irregularities in procedure, effectively prevents any chance of useful work being performed. I need not add that, in my opinion, the entire system of conducting these Conferences urgently needs reform.

At the second Conference on September 11th, a discussion took place on "Dew Ponds," and the recommendations from the various sections to the Conference were laid before the meeting. The only two that might interest this Institution were a request for photographs of geological interest, and one for boulders that presented any unusual features, both from Section C.

Many papers of interest to mining engineers were read, the most important being :—

"The Relation between the Heating and Lighting Power of Coal-gas." By Mr. T. Fairley.

"Rapid Changes in the Thickness and Character of the Coal-measures of Staffordshire." By Mr. W. Gibson.

"The Coal-fields and Iron-ore Deposits of the Provinces of Shansi and Honan, and Proposed Railway Construction in China." By Mr. J. G. H. Glass.

"Power Generation : Comparative Cost by the Steam-engine, Water-turbine and Gas-engine." By Mr. J. B. C. Kershaw.

"A Possible Coal-field in the London Basin." By Prof. W. J. Sollas.

"Note on the Re-heating of Compressed Air." By Mr. W. G. Walker.

Discussion on the Conditions during the Growth of the Forests of the Coal-measures.

Amongst the excursions may be noted a whole day excursion to the Ackton Hall collieries, and a half-day visit to the Low Moor iron-works.

Section G, which has hitherto borne the title of Mechanical Science, will henceforward be known as the Engineering Section. Under its new name it will no doubt appeal more directly than hitherto to mining engineers, and it may be hoped that papers on mining engineering will be forthcoming.

I am, Gentlemen,
Yours obediently,
HENRY LOUIS.

The CHAIRMAN (Mr. H. C. Peake) moved that a hearty vote of thanks be accorded to Prof. Louis for his services as delegate and for his report.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Mr. JAMES MCMURTRIE read the following paper on "The Geological Features of the Somerset and Bristol Coal-field, with Special Reference to the Physical Geology of the Somerset Basin":—

THE GEOLOGICAL FEATURES OF THE SOMERSET AND BRISTOL COAL-FIELD, WITH SPECIAL REFERENCE TO THE PHYSICAL GEOLOGY OF THE SOMERSET BASIN.

By JAMES McMURTRIE, F.G.S.

I.—Introduction.

The Institution of Mining Engineers having for the first time in its history decided to hold a meeting at Bristol, the Local Committee have thought it desirable that there should be a paper on the Geology of the Somerset and Bristol Coal-field, within which the Institution has now met, and while they cannot offer examples of those great mining undertakings which distinguish the Midland and Northern districts of England, they would venture to hope that it may be not unprofitable to consider the physical geology of a district which presents features of exceptional interest not met with elsewhere in this country.

The earlier proceedings of the North of England Institute of Mining and Mechanical Engineers contain papers dealing with this subject from various points of view. Valuable papers were written by Mr. George C. Greenwell,* whose former residence at Radstock enabled him to speak authoritatively on that part of the coal-basin, and more recently by the late Mr. Handel Cossham† and Dr. Saise,‡ whose intimate connexion with the Gloucestershire area enabled them to furnish much useful information on that portion of the coal-field. But the papers referred to are not generally accessible to the members of the enlarged Institution, which has since merged in one the various Mining Institutes throughout the country; and as time has gone on, additional light has been thrown upon the subject.

In deference to the wishes of the Local Committee, therefore, the writer has endeavoured to give a summary of much that he has

* *Trans.*, vol. ii., page 258; and vol. x., page 105.

† *Trans.*, vol. x., page 97. ‡ *Trans.*, vol. xxvii., page 87.

already written, together with particulars of the later discoveries made in this interesting coal-field.* A subsequent paper will deal with the methods of working, which, owing to the thinness of the seams and the disturbed character of the Coal-measures, have presented difficulties not met with in the more favoured parts of England.

II.—The Geographical Outline of the Coal-field.

The Somerset and Bristol Coal-field, so far as at present known, extends from Cromhall on the north to Frome on the south, a distance of 26 miles, and from Bath on the east to Bristol on the west, a distance of 12 miles, or, including the outlying Nailsea coal-basin, a total width of 24 miles, and according to the *Report of the Royal Coal Commission*, it includes a total area of 238 square miles. Although it embraces so large a district, the Coal-measures are only visible on the surface within about one-fifth of the entire area, the remaining four-fifths being covered by newer formations which will presently be described. Omitting the Nailsea coal-basin, which has been partly cut off from the rest by an elevation of the older rocks, the coal-field may be divided as follows:—

	Acres.
Exposed Coal-measures	30,580
Covered by newer formations	122,200
Total area of Coal-measures	152,780

It will thus be seen that the study of this coal-field is attended with many difficulties from which the better-known coal-fields of this country are altogether free. In most of these, the Coal-measures crop out at the surface in regular succession, and it only requires a careful survey to map their outlines correctly; but in Somerset it is only at a few points far apart, where the overlying strata have been denuded, that the coal-field is met with on the surface, so that in attempting to arrive at its outline new difficulties present themselves.

The Geological Survey maps show very correctly those portions of the Coal-measures, which are actually exposed. It must be obvious, however, that an ordinary geological map, however good and accurate, can convey but an imperfect impression

* *Transactions of the South Wales Institute of Engineers*, 1880, vol. xii., page 424.

of the extent of the coal-field under consideration, and that it is only by constructing a geological map, in which the covering of more recent strata has been omitted, that an adequate idea can be obtained of the area of the district. In constructing such a map, it is necessary to recall the condition of things over a large portion of the south of England, at an early period of its unwritten history, and to reconstruct the coal-field as it must have appeared after the Carboniferous strata had been successively deposited, broken up and denuded, and before the first thin layer of New Red Sandstone had been deposited on their surface.

The attention of the members is directed to the accompanying diagram (Fig. 1, Plate XII.), in which the geographical outline of the known coal-field has been mapped on this principle, showing only the actual outcrops of the Old Red Sandstone and Mountain Limestone, which are the great boundary-stones of the coal-field, and within which the writer has endeavoured to define with as much accuracy as the circumstances have permitted the various divisions of the Coal-measures, which will be described in this paper.

It will be seen that, so far as at present ascertained, the coal-field is bounded on the south by the Mendip hills, an elevation of the older rocks ranging nearly east and west from Frome to Weston-super-mare, whence it crosses the Bristol Channel to Cardiff, Gower and Pembroke, and forms the southern margin of the South Wales coal-field, of which the Somerset basin is obviously a part. Towards Frome, the Mendip range gradually descends to the level of the surrounding country, and then disappears beneath the overlying rocks, which become of great thickness in passing across the south-east of England; but observations in the neighbourhood of Frome show that the Mendip chain does not end there, and geologists have taught mining-engineers to recognize its counterpart in similar elevations of the older rocks which are met with on the southern margin of the coal-fields of France, Belgium and Germany. If these far distant phenomena are really identical, it would tend to prove that the coal-fields of South Wales, the Forest of Dean and Bristol, once probably joined together, are analagous to, if not identical with, the Continental coal-fields referred to; so that, as the writer and others have long held, the discovery of coal at Dover is only what might

naturally have been expected—a remark which may also apply to the intervening area, of which more hereafter.

Similar elevations of the older rocks bound the Somerset and Bristol Coal-field more or less on the west and north, between Broadfield Down, Bristol, Almondsbury and Cromhall; but to the west of Broadfield Down comes in the Nailsea coal-basin, to which no western limit has been discovered. Moreover, as is well known, the excavations for the Severn tunnel proved the existence of Coal-measures far to the west of the Gloucestershire portion of the coal-basin, thus indicating possible extensions of which more may yet be discovered.

From Cromhall, the older rocks curve round to the southward by Wickwar and Chipping Sodbury to Wick, between which point and Frome there are no surface-indications of the eastern boundary of the coal-field; but observations in the interior of the coal-basin point to a probable limit in that direction, and a trial-shaft sunk at Batheaston many years ago by Mr. William Smith, the father of English geology, has established the eastern margin of the basin. Although this eastern limit may exist, however, it has already been pointed out that there are great possibilities throughout the South-east of England: for, just as the South Wales coal-field has been separated from the Forest of Dean, and the Forest of Dean in its turn has been cut off from the Bristol coal-field by subordinate elevations of the older rocks, so the last-named coal-field may only have been similarly cut off from undiscovered coal-fields lying farther east, possibly not continuous but forming a chain of basins in the area intervening between Frome and Dover.

Although the Somerset and Bristol coal-field is practically one, it has been divided into two subordinate basins by the Kingswood anticlinal which runs east and west between Bristol and Warmley, and each of these areas possesses features of special interest.

III.—Horizontal Sections.

Attention may now be directed to two sections of strata which cross the district from east to west and from north to south, giving a good general view of the geological structure of the coal-field.

The first section extends from Chewton Mendip to Combe Down, near Bath (Fig. 2, Plate XIII., and the dotted line, A to B,

in Fig. 1, Plate XII.). It was originally prepared by the writer for the purposes of the Royal Coal Commission; but, except in one particular, subsequent investigation has not altered it in any way, and it may be regarded as a typical section of the district. Commencing with the Mendip anticlinal, it passes through Chewton Mendip, Farrington, Paulton, Camerton and Dunkerton, and terminates at Combe Down church. It crosses nearly at right angles the best proved and least disturbed portion of the Radstock area, and it attempts to define the probable point at which the Mountain Limestone will again emerge from beneath the Coal-measures on the eastern side of the coal-basin. The position of the different veins and groups has been ascertained by pits and borings or by underground levellings; and as the section embodies the results of every exploration down to the present time, it is probably as near an approximation to the truth as can be made until the district has been more fully developed.

The anticlinal structure of the Mendip range, and its bearing on the mineral prospects of the country south of that range, will be referred to in a subsequent part of the paper.

The second section, which also begins with the Mendip anticlinal, extends from Vobster on the south, through Radstock, Timsbury, Farmborough, Keynsham and Mangotsfield to Cromhall on the extreme north (Fig. 3, Plate XIII., and the line, C to D, on Fig. 1, Plate XII.). The southern portion of this section was constructed by the writer for the purpose of the Royal Coal Commission, but its extension north of Farmborough was prepared by Mr. John Anstie, who was associated in the local work of the Commission. The southern end of the section between Vobster and Farmborough has been based on facts proved at the Vobster, Radstock, Clandown, Camerton and Timsbury collieries, and for all practical purposes may be taken as correct. It will be observed that while the Mendip hills at Vobster exhibit the same anticlinal form, they present a much steeper inclination than at Chewton, being in places almost vertical, and that the adjoining Coal-measures exhibit physical disturbances of a remarkable character which will be dealt with at greater length later on.

Between Farmborough and Keynsham, where no practical mining-operations have been attempted for many years, the section is involved in much obscurity, and while it shows one view which

has been taken of this locality, it must be accepted with great reservation, especially north of Farmborough, an area which has hitherto baffled all attempts at solution.

From Keynsham to Cromhall, the section is approximately correct, and it shows the general structure of the Kingswood anticlinal and of the Gloucestershire end of the coal-field.

Dealing first with the southern or Radstock portion of the district, the writer will now describe the various subdivisions of the Coal-measures, as they occur in the section from Chewton to Combe Down already referred to (Fig. 2, Plate XIII.), beginning with the overlying formations.

IV.—Overlying Formations.

The presence of overlying formations is a remarkable feature of the Somerset coal-field, and they are nowhere seen to greater advantage than in the line of country through which the section shown in Fig. 2 (Plate XIII.) passes. Beginning with the Bath end of the section, the Coal-measures are there overlain by the Great or Bath Oolite, Fullers' Earth, Inferior Oolite, Lias, Rhætic and New Red Sandstone; but in proceeding westward, these are seen to have been partly removed by denudation, and crop out in succession until in the lower ground towards the centre of the coal-basin the New Red Sandstone alone remains. Proceeding farther westward we find that the New Red Sandstone is again capped by Rhætic and Lias, and in the Kilmersdon area by the Inferior Oolite, a thin covering of which is met with on the lower slopes of the Mendip hills between Mells and Frome.

The Great Oolite supplies the celebrated Bath freestone, of which large quantities are forwarded annually to all parts of England. It has been worked in the neighbourhood of Bath from an early date, sometimes in open quarries, but more extensively by mining, a remarkable example of which at Box, near Bath, will be visited during one of the excursions. The stone, which is there of great thickness, is worked by mining on a very large scale, large trolleys being conveyed direct into the interior of the workings to receive their load.

The Fullers' Earth is another valuable deposit connected with the coal-field. After having been worked in former times, the workings were abandoned, but the industry has been revived in

recent years, and a considerable quantity is again being raised in the neighbourhood of Wellow and Midford.

The Lias produces a useful building-stone, a valuable hydraulic lime, and a plentiful supply of clay well adapted for brick-making.

Although the presence of these formations has doubtless added to the difficulty of searching for coal, the New Red Sandstone is the only one which presents any real difficulty in mining. The New Red consisting for the most part of the soft and treacherous Keuper Marls, which are heavily watered and often inclined to run, a large outlay is often necessary in sinking through them. Near the base of the New Red Sandstone, however, there occurs throughout the greater part of the coal-basin, a bed of grit or conglomerate locally termed "millstone," which is so remarkably impervious to water that it holds up the surface-drainage of the country, and when shafts are once tubbed from that point to the level of the valleys, the Coal-measures beneath are found to be comparatively dry.

In the north-and-south section (Fig. 3, Plate XIII.) between the Mendip hills and Farmborough, the same general conditions prevail, the Coal-measures being there overlain by various formations from the Inferior Oolite down to the New Red Sandstone. A little to the north of Farmborough, the Carboniferous strata are found on the surface, and excepting in one or two isolated areas where brought in by faults, the overlying formations are not again seen until the section approaches Keynsham. Between that point and the Willsbridge cutting, on the Mangotsfield railway, the Lias and New Red Sandstone are again continuous, but they disappear at a fault in that cutting, and proceeding northward through the Gloucestershire coal-basin the Coal-measures are for the most part met with on the surface.

Although the overlying formations are thus absent to a great extent in this northern area, it does not necessarily follow that they were not deposited there, for their presence in the surrounding country, as well as in occasional outliers within the coal-field is evidence to the contrary. Their absence is probably due to the greater elevation of the Coal-measures at the northern end of the coal-basin, and to subsequent denudation. As a consequence of their surface-exposure, the Coal-measures there are for the most part more heavily watered than elsewhere.

It will be observed by a reference to both of the sections (Fig. 2, Plate XIII., and Fig. 3, Plate XIII.) that, with one or two exceptions, the overlying formations are comparatively level, the numerous valleys which intersect the district being valleys of denudation. At first sight, it would seem difficult to realize this, the small streams which now traverse the district being apparently insufficient to produce such great physical effects, but from personal observations during a long residence in the district, the writer is unable to attribute them to any other cause. These valleys, gradually deepened by streams fed by the rainfall of the country, are being constantly widened by landslips and denudation which, in the long course of years, have formed these beautiful "combes" so characteristic of this part of England.

The thickness of the overlying formations varies a good deal in different parts of the district, as shewn in Table I.

TABLE I.—THICKNESS OF OVERLYING FORMATIONS.

Formations.	Chewton.	Farrington.	Tyning Pit, Radstock.	Braysdown	Trial Pit, Batheaston.
	Feet.	Feet.	Feet.	Feet.	Feet.
Inferior Oolite	—	—	—	26	—
Lias and Rhætic ...	158	—	35	116	277
New Red Sandstone	208	80	186	176	54
Totals	366	80	221	318	331

These local variations within the coal-field, however, are trifling when contrasted with the thickness of the same formations beyond the limits of the coal-basin. The late Mr. Charles Moore, of Bath, gave the striking comparison shewn in Table II. in one of his ably-written papers. This striking contrast, Mr. Moore attributed to the Mendip hills, which proved a barrier to the incursion of the Mesozoic seas within their northern borders; but he rather understated the thickness of overlying strata within the coal-basin, the depth to the Coal-measures at some collieries being as much as 318 feet.

In reflecting on the numerous formations by which the Somerset coal-field is overlain, a more hopeful view may be taken of other districts where the existence of coal is at present unknown. Had the northern, central and southern parts of the coal-basin

(which form only a small portion of the whole) been as completely covered up by Mesozoic strata as other parts of the district, it might have been supposed that no coal-field existed in the county, or that if it existed at all, it lay at an enormous depth. This reflection induces the hope that under many parts of the country now believed to be barren, or in which coal is supposed to be hopelessly buried beneath more recent strata, it may yet be found within workable depth.

TABLE II.—THICKNESS OF OVERLYING FORMATIONS.

Formations.	Without the Coal-basin. Greatest thickness. Feet.	Within the Coal-basin. Least thickness. Feet.
Triassic	2,000	50
Rhætic	50	50
Lower Lias	700	2
Middle and Upper Lias	500	42
Inferior Oolite	170	25
Totals	3,420	169

V.—COAL-MEASURES.

Between the Secondary formations and the Carboniferous strata to which attention is now directed, there are many points of striking contrast. The former bear little evidence of disturbance, they occupy a nearly horizontal position, and they are all approximately conformable with each other. The latter on the contrary exhibit marks of great disturbance, they are more or less highly inclined, and they are consequently not conformable with the overlying rocks. In the section from Chewton to Bath (Fig. 2, Plate XIII.) the Coal-measures form a perfect basin, and towards the centre very gentle inclinations prevail, but in approaching the margin, where the strata have been tilted during the elevation of the older rocks, very high inclinations prevail—30 to 40 degrees being not unfrequent. In the north-and-south section (Fig. 3, Plate XIII.), the basin is of a more undulating character and may almost be described as a series of subordinate basins. A period of great denudation however must have followed the elevations to which the Coal-measures owe their present form, for their upturned edges have been washed off, and the Mesozoic beds have been deposited on a comparatively level surface.

In treating of a formation so extensive within the limits of this paper, it is obviously impossible to enter into many details, and attention will therefore be directed to those broader features which are likely to be of general interest.

a.—Upper Division.

The Coal-measures have been separated vertically into two great divisions by the intervention of a great thickness of Coal-measure sandstone, well known in this and other districts as the Pennant Rock. The Upper Division includes all the coal-bearing strata above the Pennant Rock; the Lower Division takes in all the strata intervening between the Pennant Rock and the Millstone Grit; and each of these divisions is in its turn separable into two distinct groups or series of coal-seams.

TABLE III.—RADSTOCK SERIES OF COAL-SEAMS.

Names of Coal-seams.	Thickness. Ft.	Ins.
Withy Mills Seam	1	4
Great Vein	2	2
Top Little Vein	1	4
Middle Vein	2	2
Slyving Vein	2	4
Under Little Vein	1	2
Bull Vein	2	2
Nine-inches Vein... ... 9 inches to	1	0
Total ...	13	8

Radstock Series.—Dealing first of all with the Radstock district, where the Upper Coal-measures are most largely developed, the Upper Division embraces what are locally known as the first or Radstock, and the second or Farrington series of seams. These are separated from each other by 550 to 750 feet of unproductive strata, near the middle of which occur certain well defined beds of red shale from 130 to 250 feet thick, which form a well marked line of separation between the two groups. The Radstock series consists in all of the eight seams set forth in Table III. The total thickness is barely sufficient to form three average seams, and in no case is the whole thickness available in any one place. The Withy Mills vein and the Nine-inches vein are seldom found in a workable state, and the former is absent over the greater part of the district. The Great vein in going northward towards Clutton, the Middle vein towards Camerton

and Timsbury, and the Slyving vein in extending eastward from the Middle and Ludlows pits at Radstock, become divided into two parts, with several feet of strata between, and in each case only one portion of the divided seam is generally workable. The Top Little and Under Little veins vary comparatively little, but in the parishes of Camerton and Timsbury, the Bull vein thins out to a few inches, and becomes unworkable.

The coal produced from this series is chiefly used for household purposes and gas-making, and from this thin and apparently unimportant group of veins, the south-west of England has derived no inconsiderable part of its supply for the last hundred years. The secret of such seams being workable lies mainly in their geographical position, and although the railway companies have done their best to annihilate space by preferential rates, yet the situation of this, the southernmost coal-field of England, has enabled it to be worked with advantage to its owners and to the community at large.

Red Shales.—The Red Shales, to which allusion has been made, appear to be ordinary shales, from which they differ only in colour, the colouring-matter being probably derived from a small percentage of iron which they contain.

Although not generally recognized in the Gloucestershire coal-basin, it is probable that certain red beds met with in the sinking at Parkfield, north of Bristol, may be found to correspond; but in that locality denudation seems to have removed the Radstock series of veins, which should otherwise have been met with immediately above these shales. It has been suggested that these Red beds may probably be found to have a much wider range than is generally supposed, as similar beds are found in some parts of the Midland coal-field.

TABLE IV.—FARRINGTON SERIES OF COAL-SEAMS.

Names of Coal-seams.	Thickness. Ft.	Ins.
Cathead Vein, in 3 pieces	2	4
Top Seam, in 2 pieces	1	9
Peau or Peacock Seam, in 3 pieces ...	1	2
Middle Seam, in 2 pieces	2	4
Church Close Seam or New Vein, in 2 pieces	1	8
Seventeen-inches Seam	1	5
Total ...	10	8

Farrington Series.—The second or Farrington series, which derives its name from the Farrington colliery, where it was first worked to any notable extent, usually consists of six veins: but it is much more variable than the upper series, sections taken at different parts of the basin differing so materially one from the other, that it has been found difficult to correlate the veins, which consequently are known by different names in different parts of the district. Table IV. is a list of the seams met with in the original sinking of Farrington pit, which may be regarded as a typical example of the group.

TABLE V.—SECTION OF STRATA SUNK THROUGH IN THE FARRINGTON PIT BELOW THE CHURCH CLOSE SEAM.

No.	Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
	Church Close Seam or *Bottom Vein*—				
1	**COAL** ... Ft. 0 In. 6				
2	Bending 0 6				
3	**COAL** ... 1 2				
		2	2	553	0
4	Strong clift	14	4	567	4
5	Mild clift	6	0	573	4
6	Soft clift	12	0	585	4
7	Pan	3	4	588	8
8	Clift	18	0	606	8
9	Pan	2	3	608	11
10	Soft clift	6	5	615	4
11	**COAL**	0	4	615	8
12	Pan and black shale	21	4	637	0
13	**COAL** ... Ft. 0 In. 3				
14	Shale ... 0 6				
15	**COAL** ... 0 9				
		1	6	638	6
16	Pan and shale ...	4	6	643	0
17	Clift and shale ...	42	0	685	0
18	**COAL**	0	6	685	6
19	Pan, hard, mixed with greys ...	10	6	696	0
20	**COAL**	1	0	697	0
21	Soft pan	4	2	701	2
22	Greys	8	10	710	0
23	Hard clift	3	9	713	9
24	**COAL**	0	2	713	11
25	Soft pan	4	0	717	11
26	**COAL**	trace		717	11
27	Pan	25	0	742	11
28	Dark clift	0	6	743	5
29	**COAL** ... Ft. 1 In. 0				
30	Benching 0 1½				
31	**COAL** ... 0 6½				
32	Soft pan 1 0				
33	**COAL** .. 0 2½				
		2	10½	746	3½
34	Pan...	4	6	750	9½
35	Clift	4	11	755	8½
36	Shale... ... Ft. 0 In. 10				
37	Soft blacks 0 9				
38	Blacks and Stone .. 0 4				
		1	11	757	7½
39	**COAL**	1	3	758	10½
40	Soft pan...	2	6	761	4½
41	Clift	3	0	764	4½
42	Soft stone	0	6	764	10½
43	**COAL**	1	9	766	7½
44	Clift	5	0	771	7½
45	**COAL**, stony ...	2	1	773	8½

Within the past two years the Farrington pit has been deepened to other seams not previously met with, and the writer is indebted to Mr. R. F. Bennett, manager to Messrs. Beauchamp, the owners of the colliery, for the particulars (recorded in Table V.) of the

additional strata thus proved, which will be of considerable interest to others in the district.

TABLE VI.—SECTIONS OF COAL-SEAMS AT GREYFIELD COLLIERY.

Names of Coal-seams.	Thickness. Ft.	Ins.	Thickness of Good Coal. Ft.	Ins.
First Vein.				
COAL	1	5	1	5
Streak Vein.				
COAL, inferior ...	1	0		
Stone	0	2		
COAL	0	8		
Stone	0	10		
COAL	1	6		
Total	4	2	3	2
Peacock Vein.				
COAL	1	6		
Shale	0	0½		
COAL	0	3½		
Total	1	10	1	9½

Names of Coal-seams.	Thickness. Ft.	Ins.	Thickness of Good Coal. Ft.	Ins.
Dabchick Vein.				
COAL, and Shale	0	4		
COAL	1	2		
Shale	0	1		
COAL	1	2		
Total	2	9	2	4
New Vein, correlated with the *Church Close Seam.*				
COAL	0	7		
Parting	0	0½		
COAL	1	6		
COAL	0	8		
Pan	0	3		
COAL	0	3		
Total	3	3½	2	2

As another example of the second series, Table VI. is a summary of the seams found at the Greyfield colliery, Clutton, the property of the Earl of Warwick, omitting one or two thin beds of coal, which are not recognized seams. At Greyfield colliery, also, an effort has lately been made to discover lower seams, by means of a level branch driven across the deeper measures from the bottom of the shaft at the New vein. From information kindly supplied by Mr. Watson, the manager, it appears that a coal-seam has been cut and is now being worked at a distance of 450 feet from the shaft. He has called it by the suggestive name of the Bantam seam, and gives the following section:—

	Thickness. Ft.	Ins.
COAL, good	1	0
Shale	0	7
COAL	0	5
Total	2	0
Good coal	1	5

The branch has since been extended to a total distance of 900 feet from the shaft, in the hope of cutting the Rudge seam

(formerly worked at the adjoining Rudge pit, and said to have been 14 or 15 inches in thickness and of good quality), but the driving has not yet reached its destination.

These seams appear to lie in the upper beds of the Pennant Rock, the intermixed strata being chiefly of that character.

Although the seams of the Farrington series are generally six or eight in number, not more than four or five are usually workable, and the quality is not quite equal to the Radstock seams; but with the diminishing area of coal left in the upper series, attention has latterly been more directed to these lower seams, which must take a more important place in the future. Within the last fifteen years, three collieries have been sunk deeper to win them, including the Middle and Ludlows pits at Radstock belonging to Earl Waldegrave, and the adjoining Lower Writhlington colliery, where they are now being worked with a considerable amount of success. The deepest of these sinkings is the Middle Pit, where the No. 6 or bottom seam was cut at 1,794 feet; a great depth to go for seams of such moderate thickness; but the coal finds a ready market for household, gas and manufacturing purposes, and as time goes on other sinkings are likely to follow.

TABLE VII.—SECTIONS OF COAL-SEAMS AT PARKFIELD COLLIERY.

Strata.	Thickness of Coal-seams. Ft.	Ins.	Depths from the Surface. Feet.
New Red Marl			183
Red coal-shale			426
Shale and sandstone			543
Rag Seam, unworkable	1	6	
Shale and sandstone			591
Hard Seam...	1	10	
Shale			660
Stinking Seam, unworkable, 6 inches to ...	2	0	
Shale and sandstone			705
Top Seam	2	4	
Shale			777
Hollybush Seam	3	0	
Fire-clay			780
Great Seam...	2	10	
Total ...	13	6	

As an example of these sinkings in the centre of the basin, the Ludlows pit, Radstock, has passed through both the Radstock and Farrington series. The strata consists of alternations of blue

shale, locally called "clift," and grey sandstone locally termed "greys," the former largely predominating, and the total thickness of the strata in the upper division towards the centre of the Radstock coal-basin cannot be far short of 2,200 feet.

The group of veins known in Somerset as the Farrington series are undoubtedly identical with the Parkfield and Coalpit-heath seams of Gloucestershire, although the latter are on the whole of greater thickness and differ in some respects.

Table VII. records a section of the Parkfield colliery, which may be regarded as typical of the northern coal-basin. Deducting the thickness of the Rag and Stinking coal-seams, which are generally unworkable, this leaves 10 feet of workable coal in the remaining four seams, which are said to be very uniform throughout the Gloucestershire basin.

b.—Pennant Rock.

Next in descending order comes the Pennant Rock, which attains a very great thickness throughout the coal-field. In the Bristol area, it has been estimated at 1,840 feet; but in Somerset, where no sinking has ever penetrated through it and where it is largely covered by Mesozoic rocks, its thickness is more difficult to ascertain. A little to the south of Pensford, its outcrop extends for a distance of 6,000 feet at an inclination of 18 degrees, equal to a vertical depth of 1,880 feet. At Temple Cloud, near Clutton, its outcrop may again be followed for nearly 1 mile to the west of Greyfield pit, the inclination ranging from 10 to 25 degrees and showing a vertical depth of 1,700 feet. Further, at Holcombe, near Radstock, it can be traced more or less for 3,000 feet at an angle of 50 degrees, implying a vertical thickness of 2,500 feet.

In none of these instances, however, is the whole of the Pennant Rock exposed, and other investigations have led to the conclusion that in the southern part of Somerset it cannot be less than from 2,500 to 3,000 feet thick. In lithological character, it differs little from the same rock in the Forest of Dean and South Wales, from a locality in which it has derived its name; and it has been extensively worked for many years in both Gloucestershire and Somerset for various industrial purposes.

Although of such enormous thickness, so far as at present

known it is almost entirely unproductive of coal. In the Somerset basin, at Lookham Wood, near Holcombe church, several thin seams called the Lookham seam, Gent's course and North course appear to have been worked many years ago in the lower beds of the Pennant Rock, and more recently a thin seam of coal associated with fire-clay was worked in it at Temple Cloud, but the undertaking is said to have been unremunerative and has for some time been abandoned. According to the *Report of the Royal Coal Commission*, four seams called the Cock, Chick, Hen and Stinking seams were worked on the north side of the Kingswood anticlinal in the Pennant Rock; and it is stated in the same report that the uppermost veins of the Kingswood group or lower division, including the Fig, Francombe, Millgrit, Rag and Devils seams, appear to lie within the lower beds of this great body of sandstones, to which the Graces seam in the Nailsea coal-basin is also said to belong. For the most part, however, the Pennant Rock is barren ground, and it will be one of the mining problems of the far distant future to find means of sinking through this heavily-watered ground to the Lower Division of the Coal-measures, as has already been done in South Wales where the Pennant Rock is of a less formidable thickness.

c.—Lower Division.

The Lower Division, which embraces the whole of the strata intervening between the Pennant Rock and the Millstone Grit, underlies the entire coal-field from Cromhall in the extreme north to the Mendip hills in the south, including the outlying Nailsea coal-basin.

In the southern area, the seams of this division have been worked from very early times in the Nettlebridge valley along the flanks of the Mendip hills, between Mells on the east and Emborough on the west, partly by shallow surface-workings along the outcrops of the seams, of which many evidences remain, and partly by deeper workings in more modern times. Some of these more recent undertakings at Mells, Vobster, Newbury, Edford, and New Rock have worked the seams of this division extensively, and considerable quantities are being raised from it now; but owing to the disturbed character of this part of the coal-field, it is not now worked so generally as in earlier times, and many of the seams have not been touched at all for a long series of years.

In the year 1824, however, when mining-operations were carried on over a more extended area, Dean Buckland visited the district, and having consulted the best informed local men and devoted much time to the investigation of the subject, he, jointly with Conybeare, contributed an able paper which appeared in the *Transactions of the Geological Society* of that year and remains a valuable work of reference to this day. He may possibly have multiplied the number of seams, owing to the same seams being known by different names at different collieries; but as the result of his enquiry he enumerated no less than 37 seams belonging to this division, and omitting three of these which lie in the under beds of the Pennant Rock, and others which are thin and worthless, there remain 26 workable veins belonging to the division, of which the higher veins fall within what is known as the New Rock series, and the lower within the Vobster series.

There is no special line of demarcation between these groups, which have taken their names from certain collieries with which they have been identified, and the distinction between them consists chiefly in the character of the seams and of the strata among which they have been deposited. In the New Rock series, especially between the upper seams, hard sandstone prevails, differing little in appearance from the Pennant Rock, of which some might consider it a part. This group is probably the equivalent of the Lower Pennant series of South Wales and produces chiefly a house and manufacturing coal. The strata of the Vobster series, on the other hand, which consist for the most part of extremely tender shales, are probably the equivalent of the White Ash series of South Wales, and yield a smithy and coking coal of great purity, from which the iron-works (formerly at Seend and now at Westbury) have derived a considerable part of their supplies. Table VIII. embodies a list of the seams contained in this division.

The veins between the Globe and the Hard Coal veins, having all been proved in recent years, that part of the section may be taken as practically correct, but a number of the veins are generally unworkable. Most of the veins from the Fern Rag downward have also been worked extensively; but the middle part of the section, having lately been little explored, has been compiled from earlier records in which the same seam may

possibly have been repeated under different names, and it must therefore be received with some degree of reservation.

Clayband ironstone in bands and nodules prevails in the lower part of this division, very much as in South Wales. Associated with the Dunny Drift vein at Newbury colliery, is a peculiar coarse granular bed of ironstone from 4 to 6 inches thick; but no attempt has ever been made to turn these ores to any practical advantage, and in these days of imported ores and steel-manufacture they may be considered as valueless.

TABLE VIII.—LOWER DIVISION OF COAL-SEAMS.

Names of Coal-seams.	Thickness. Ft. Ins.	Thickness. Ft. Ins.
New Rock Series :		
Globe Vein	3 0	
Small Coal Vein	3 0	
Two Coal Vein	2 0	
Warkey Course Vein	5 0	
Garden Course Vein	3 6	
Strap Vein	2 6	
Great Course Vein	4 0	
Firestone Vein	3 0	
Little Course Vein	1 6	
Dunny Drift Vein, 2 feet to 5 feet	3 6	
Hard Coal Vein	3 0	
Perkins Course Vein	2 0	
Foot Coal	2 0	
Branch Vein	4 0	
Golden Candlestick Vein	2 6	
North Shoots Vein	4 0	
South Shoots Vein	3 0	
Standing Coal	4 0	
	——	55 6
Vobster Series:		
Fern Rag Vein	2 0	
Stone Rag, 2½ feet to 6 feet, say	4 0	
Main Coal, with shaley coal	8 0	
Strap Vein	3 0	
Perrink Vein	3 6	
White Axen Vein	3 0	
Red Axen Vein	3 0	
Wilmotts Vein	1 6	
	——	28 0
Total ...		83 6

The thickness of strata between the Pennant Rock and the Millstone Grit may be taken at 2,800 feet, and to summarize the previous figures, the following is the total estimated thickness of the Coal-measures in the Somerset basin.

	Feet.
Upper Division	2,200
Pennant Rock	3,000
Lower Division	2,800
Total ...	8,000

Between the Vobster and Nettlebridge district, which has now been described, and the collieries in the neighbourhood of Bristol, practically nothing has been done to develop the Lower Division. A trial-shaft was sunk many years ago at Buckland Dinham, near Frome, which reached a depth of 840 feet, and left off in New Red Sandstone. The exploration was afterwards continued by means of a boring from the bottom of the shaft, proving the Coal-measures which were there found to be in a nearly vertical position, and the undertaking was ultimately abandoned. At Chewton Mendip and Widcombe, the seams of the lower division have also been proved by borings, and although these have not yet led to any practical result, they will doubtless lead to the ultimate development of this group; but with these exceptions the entire range of the lower measures between Nettlebridge and Bristol is still virgin ground.

Through the agency of the Kingswood anticlinal, which brought its seams within easy reach, the lower division has been extensively worked from very early times, in a broad belt extending east and west across the entire coal-field from Ashton Vale to Warmley, and it is within this range that the important collieries of Ashton Vale, Malago Vale, Bedminster, Easton, Hanham and Kingswood have been carried on. The correlation and succession of the seams at these collieries is not altogether free from doubt, but the list recorded in Table IX. and taken from the *Report of the Royal Coal Commission* is approximately correct.

It is impossible to correlate any of these Kingswood seams with those worked in the southern area, but the same general characteristics prevail, the Bitton and Kingswood seams being the equivalent of the New Rock series, as those of Ashton Vale are doubtless the counterpart of the Vobster seams. On the southern side of the anticlinal, these lower seams have been worked for considerable distances into Somerset, the workings passing with a southerly dip under the Pennant Rock; but their extension northward into Gloucestershire has been cut off by a great east-and-west fault at

Soundwell colliery, a little to the north of the ridge, which for many years baffled all attempts to unravel the structure of the district.

TABLE IX.—COAL-SEAMS AT BITTON, BRISTOL, ETC.

Names of Coal-seams.	Thickness. Ft.	Ins.
Bitton :		
Buff Seam, 1 foot to 8 feet, average ...	4	6
Parrot Seam, 12 to 21 inches, say	1	6
Little or Brimstone Seam, bad	1	0
Mixen Seam, bad	4	0
Kingswood and Bitton :		
Stibbs' First Seam	1	3
Stibbs' Second Seam	3	0
Stibbs' Third Seam	2	0
Stibbs' Fourth Seam	2	0
Stibbs' Fifth Seam	1	0
Hard Vein Seam	1	2
Queen Bower Seam, 1 foot to 7 feet, average	4	0
Doxall Seam	1	10
Upper Five Coals or Rock Seam	2	0
Primrose Seam...	2	0
Old Toad Seam	2	3
Trow or Through Seam	1	0
Red Ash Seam..	1	4
Bristol and Kingswood :		
Hole or Hard Seam	1	2
Five Coal Seam, 4 feet to 5 feet, average ...	4	6
Thurfer Seam	2	3
Kingswood Great Seam	4	6
Gillers Inn Seam	1	6
Little Toad or Two-feet Seam	1	9
Parker's Top Seam, 3 feet to 6 feet, average	4	6
Parker's Middle Seam	2	6
Parker's Little Seam, 1 foot to 3 feet, average	2	0
Ashton Top Seam	2	6
Ashton Great Seam, 1 foot to 4 feet, average	3	6
Ashton Little Seam	2	0
Total ...	68	6

In a later part of this paper, further reference will be made to this fault, which so long retarded the northward development of the Kingswood coal-field, and owing to which but little is known of the condition of the lower division in the Gloucestershire coal-basin. But, judging from facts ascertained at Yate and Cromhall, a great shrinkage of the seams must take place in proceeding northward, for the 29 seams of Kingswood colliery are

represented by about 4 seams at Yate and 2 at Cromhall, with less than 20 feet of coal, and no collieries are now working in that area.

Nailsea Coal-basin.—In the Nailsea coal-basin to the west, the lower division appears to be also represented by a much smaller number of seams than at either Kingswood or Nettlebridge; and it is to be regretted that owing to the heavy feeders which prevail in that area and other causes, the collieries there have for some time been abandoned. Table X. contains a list of the principal coal-seams recorded in the Nailsea basin.

TABLE X.—COAL-SEAMS OF THE NAILSEA COAL-BASIN.

Names of Coal-seams.	Thickness. Ft.	Ins.
Graces Seam	3	0
Red Ash Coal	1	0
White's Top Seam	3	6
Dungy Seam	1	4
Under Little Seam	1	2
Top Golden Valley Seam	1	8
Golden Valley Seam	2	9
Backwell Little Seam	1	9
Smith's Coal Seam, 9 inches to ...	5	0
Coal	1	6
Dog Seam	2	10
Spider Delf Coal	2	1
Crow Seam	1	2
Total ...	2	89

One favourable feature connected with the Somerset and Bristol coal-field deserves to be mentioned, namely, the absence of fire-damp, which in practice has not been met with at all in the Upper Division, and in the Lower Division is chiefly confined to the deeper seams of Vobster and the Nettlebridge Valley, Ashton Vale and Bedminster. Thus the district has, to a large extent, been spared from those disastrous explosions which unhappily occur in other parts of Great Britain.

It should also be mentioned that this coal-field is unusually rich in plant-remains, its flora being especially abundant and well preserved in the Upper Division; but with one or two exceptions it has yielded little trace of animal life of any kind having existed here during the Carboniferous period.

d.—Millstone Grit.

The Millstone Grit formation is well developed in the Gloucestershire basin, where it is met with at many points round the margin of the coal-field, and its thickness has been estimated at from 900 to 1,000 feet. In the Somerset area, where its outcrop is traceable from Mells to Nettlebridge, its thickness is not thought to exceed 500 feet; but there is no place where a continuous section of it can be obtained. Generally speaking, it is little used for industrial purposes, though in Bristol is has been employed for building, and it is easily recognizable by its highly siliceous character and pale purple colour.

e.—Mountain Limestone.

The Mountain Limestone and Lower Limestone Shales, the lowest members of the Carboniferous formation, attain a great thickness in the Somerset area. According to the memoirs of the Geological Survey, their thickness in the Avon valley, near Bristol, has been estimated at 2,340 feet; but so far as can be ascertained, their thickness on the Mendip hills between Mells and Vobster cannot be less than 3,000 or 3,500 feet. Near this point and within the limits of the coal-basin, occur three remarkable outliers of limestone to which attention will be directed in a later portion of this paper.

VI.—Physical Geology.

Faults and Disturbances.—The physical geology of the Somerset and Bristol coal-field is probably the most remarkable to be met with anywhere in Great Britain. Whatever may have been the conditions under which the Coal-measures were originally deposited, it is obvious that they have subsequently been exposed to an amount of disturbance and dislocation for which it would be difficult to find a parallel. It would obviously be impossible to deal with this part of the subject at great length within the limits of this paper, and it is therefore only proposed to describe a few of the more remarkable examples met with in the district, beginning with the Mendip anticlinal and the folded and contorted strata of the Vobster and Nettlebridge valley.

This great physical disturbance, which has long engaged the attention of geologists, stretches along the northern flank of the Mendips from Mells on the east to Nettlebridge on the west, but

whether it may extend still farther eastward it is at present impossible to say.

In the locality referred to, the Mendips may be cited as a typical example of true anticlinal structure, the central ridge consisting of Old Red Sandstone, through which large masses of trap-rock protrude at various points, and away from which the Lower Limestone Shales and Mountain Limestone dip northward and southward at high angles. Although these hills are now of only moderate height, rarely exceeding 1,000 feet, they must have been very high mountains when their elevation first took place: for from their present summits the entire Carboniferous formation, 12,000 feet thick, and an unknown thickness of Old Red Sandstone, must have been washed away. At the New Rock colliery, adjoining the range to the west, the beds of the Lower Division occupy their natural position, dipping north-eastward and conformably with the Mendips at an angle of 35 degrees; but in proceeding eastward across the main road leading from Radstock to Shepton Mallet, the strata are seen to gradually assume a vertical position. Still farther eastward, the strata are completely folded over, with a reversed dip to the south, which gradually varies from 70 degrees at Barlake to 50 degrees at Holcombe, 45 degrees at Newbury, and 20 degrees at Mells, where the disturbance probably attains its maximum.

This inversion of strata has been proved for a distance of 4 miles along the flank of the Mendips, but in the eastern workings of the Mells colliery, now abandoned, the inclination had again increased to 45 degrees, possibly indicating a return to the true northerly dip. The state of things herein described is clearly shown at the Vobster end of the north-and-south section (Fig. 3, Plate XIII.), and even more strikingly in the sections from Tyning pit to Vobster, and from the Mackintosh pit (Newbury) to the Mendip hills (Fig. 5, Plate XIV.). It will be observed that the Mountain Limestone there dips away from the Mendips at a high angle, being in places almost vertical, and that the Millstone Grit shows indications of inversion. In all probability, the denuded portion of the Mountain Limestone was more nearly perpendicular than what remains—if it was not partially folded over (which seems not unlikely), for there are three large outlying areas of Mountain Limestone lying on the top of the Coal-measures in the locality referred to, which can only be fully accounted for in that

way (Fig. 6, Plate XIV.). One of these outliers, called the Tor Rock, occurs 2,550 feet from the nearest point of the Mendips, and measures 570 feet by 390 feet. The second and largest, which occurs at Upper Vobster, is 3,450 feet from east to west, with an average width of 900 feet, and is situated 3,900 feet from the nearest Mountain Limestone of the Mendip range. The third of these outliers is at Luckington, and is shewn in the Mackintosh section. Its extreme length is 1,350 feet, it is from 150 to 360 feet wide, and it is distant 5,700 feet from the Mountain Limestone of the Mendip hills, the workings of the Newbury colliery having passed beneath it without meeting with any fault to account for its presence.

The effect of all this on the adjacent Coal-measures has been very remarkable, and is to some extent shewn in the sections (Fig. 3, Plate XIII., and Fig. 5, Plate XIV.). The Pennant Rock and the New Rock series have been folded completely over, and now dip towards the Mendips at an angle of 45 degrees. Abundant evidence of this inversion can be seen both on the surface and in the mines, where, as at the Mackintosh pit, it has been proved to a depth of 900 feet, without any apparent indication of the bottom of the fold being reached, although there must necessarily be a point lower down where the strata resume the true northern inclination.

Being chiefly composed of strong sandstones, the New Rock series has sustained comparatively little injury from the action to which it has been exposed, the strata being so regular and unbroken in their reversed position that mining is carried on there with a considerable amount of success.

Between the Millstone Grit, on the one hand, and the New Rock series on the other, the Vobster group seems to have folded over and settled down in an irregular mass, the tender shales of which it is composed being broken up and distorted to an extent for which we must seek a parallel in the Belgian coal-fields. The strata neither conform to the dip of the Mendips nor to that of the New Rock series, but lie in a succession of folds: being vertical at one point, horizontal at another, and in others presenting very varied dips, the shafts often passing repeatedly through the same seams.

With all this, however, large quantities of coking coal have been raised here, as in Belgium, under like circumstances, and

it is believed that lower down the veins will be found in a much more regular state.

The Overlap Fault of Radstock.—Overlap or slide-faults, by which the strata have been displaced horizontally rather than vertically, form a distinguishing feature of the coal-field, and they are especially numerous in the Radstock district. Sometimes they are met with in working the coal-seams, which for a short distance are doubled or trebled in thickness, not by the seams swelling out in thickness to that extent, but by two or three thicknesses of the seam having apparently been forced one over the other. In other instances, the seams in a particular group have been entirely displaced and thrust one over the other, thus doubling them to the extent of 30, 60 or 120 feet; but the overlap of Radstock so far exceeds in extent all others met with in the district that it calls for special notice.

The dislocation appears to attain its fullest development within the manor of Radstock, where all the facts connected with it have been well ascertained and established. In each of the veins of the Upper Series, the workings have been carried against the fault within the manor, several of the shafts have been sunk through it, and several drivings have been made in the leader or line of fracture, so that there have been the fullest opportunities of obtaining information respecting it. Its course has been traced from Welton colliery on the western side of the parish of Radstock to the neighbourhood of Writhlington on the eastern side; but its easterly and westerly extensions beyond those points have not been so well ascertained. At one time, it was believed that it terminated at the 600 feet fault, proceeding no farther westward; but it is now well understood that it exists at the Clandown and Welton collieries, although in that direction it probably decreases in extent.

It probably dies out before reaching Paulton: for, although that neighbourhood has been well explored, there is no mention of its having been found there. Its easterly extension through Writhlington has been satisfactorily established; but in proceeding eastward it seems to divide into a succession of overlaps, which, taken together, throw in the same extent of extra coal as at other points where there is one clearly-defined dislocation. Whether the breaking up of the fault into several parts may be

taken as an indication that we are nearing its eastern termination, is a question which we may hope one day, to solve, but it is not improbable.

In order to give a clear idea of this extraordinary dislocation, a cross-section of the strata affected is submitted (Fig. 4, Plate XIV.). The section begins a little to the north of the Tyning pit, Radstock, passes through the fault at right angles, and shows its effect on the Upper Series. The extreme extent of the overlap would be found in the centre of the parish a little farther west; but this line of section has been selected, partly because at present there are more particulars obtainable there than at any other point in the manor, and partly to take in the two smaller faults which have already been mentioned. The maximum amount of overlap may be estimated as follows:—On the Great vein, 420 feet; Top Little vein, 660 feet; Middle vein, 750 feet; Slyving vein, 1,050 feet; Under Little vein, 1,050 feet; and Bull vein, 1,080 feet. The fractured ends of the strata on the upper side of the fault have been turned downward, and those of the beds below have been turned upward at the point of fracture, the veins having been occasionally forced into a succession of small overlaps in its vicinity: the "leader" consists of a thick layer of broken and crushed strata, such as might have been produced by one ponderous mass moving over another.

The marked difference between the width of the overlap on the three upper and three lower veins of the Radstock group, is very difficult to explain. A natural inference would be that the lateral movement (whatever its cause) had commenced before the deposition of the upper veins, and that it must have been continued afterwards—either as a gradual movement, or in successive periods, which would fully account for the more limited overlap in the upper strata. Whatever the power may have been which produced this remarkable fault, it is obvious that it must have had its origin in lateral pressure, and the probability is that the elevation of the Mendips, the reversed strata of the Vobster and Nettlebridge valleys, and the overlap-fault of Radstock, all lying parallel and conterminous one with the other, are the result of one great physical disturbance. What the force may have been, which caused the elevation of the older rocks: whether it occurred through contraction of the earth's crust, or by the intrusion of trap-rock in the centre of the Mendips,

the writer does not pretend to say; but it seems evident that the elevation of the older rocks has caused the inversion of the strata of Vobster and Nettlebridge, as well as the presence of the three enormous masses of Mountain Limestone, which are found overlying the Coal-measures nearly 1 mile from the parent-rock (Fig. 6, Plate XIV.). The writer has been unable to arrive at any other conclusion than that the great lateral pressure thus thrown upon the Upper Division in the interior of the basin has had the effect of thrusting the strata forward, producing the overlap-fault of Radstock, although the effects there seen are nearly 4 miles distant from the cause which probably gave rise to them.

This view has been largely confirmed by the observations made in what may be regarded as the continental extension of the Mendip range, where there has been a similar lateral pressure from south to north, but on a scale so immense that the Coal-measures are there overlain not only by the Mountain Limestone, but in some instances by Devonian and Silurian rocks.

The 100 Fathoms Fault of Radstock, and the 70 Fathoms Fault of Timsbury.—These faults are mentioned as being the largest vertical faults met with in the Radstock basin, where similar faults of considerable size are of frequent occurrence.

The 100 fathoms or great fault extends from Timsbury southward through Clandown and Radstock to Kilmersdon, reaching its fullest development at Clandown, where it has been proved to be a downthrow west of 720 feet. The 70 fathoms fault, ranging westward from Timsbury to Temple Cloud, is an upthrow north of 420 feet. Contrary to general experience, it appears to affect the overlying rocks, the Coal-measures having there been uplifted bodily through the New Red Sandstone, which has subsequently been denuded, leaving a bold escarpment of Pennant Rock, extending from Highbury Hill westward through the Temple Cloud quarries towards Cameley.

The Farmborough Fault.—This fault, which occurs a little to the north of Timsbury, extends westward under the Barrow Hills to the north of Clutton, and was formerly supposed to be an upthrow north of 600 feet, but some engineers are of opinion that it may be a downthrow fault. It has long been a puzzle to both mining-engineers and geologists, all attempts to find the Rad-

stock seams north of it having failed; and in the Timsbury district it has hitherto formed an effectual barrier to the northward extension of mining enterprise.

A pit was sunk many years ago north of the fault and near the village of Farmborough, proving some thin coal-seams, which were thought at the time to represent the seams of the Farrington series; but after £10,000 had been spent on the adventure, the attempt was abandoned, and the mystery still remains unsolved.

The Kingswood Anticlinal and Overlap Fault.—Reference has already been made to an east-and-west fault lying immediately north of the Kingswood anticlinal, which cuts off the measures a little to the north of the Soundwell collieries, and beyond which the long list of coal-seams worked at Kingswood had not been found. Through the skill and enterprise of the late Mr. Handel Cossham, so long connected with the Parkfield and Kingswood collieries, it was ultimately discovered that this mysterious fault was an overlap of great magnitude, by which the entire Kingswood Hill had been thrust bodily forward for a distance of 1,080 feet, the Great vein, Gillers Inn vein, and Two-feet vein, at Speedwell pit, showing an overlap to that extent, combined with a downthrow to the north of 840 feet. According to Mr. Cossham's description, this fault resembles very much the overlap-fault of Radstock; and, whether it be a mere coincidence or otherwise, it is a remarkable circumstance that the extent of the overlap at Kingswood is exactly the same as on the Bull vein at Radstock, namely, 1,080 feet. The effect of Mr. Cossham's discovery was to add greatly to the resources of the Kingswood collieries, besides throwing a new light upon the northward extension of the Kingswood coal-seams under the Gloucestershire basin.

Great Fault of the Parkfield District.—The principal fault in the Gloucestershire area runs north and south through the centre of the coal-field, separating the collieries of Parkfield and Coalpit Heath and throwing down the strata eastward for a depth of 600 feet. From the great width of broken ground connected with this fault it has been thought that it may consist of two or three parallel faults making up the aggregate downthrow of 600 feet; but save this exception there is nothing connected with it calling for special remark.

VII.—Possible Coal-areas in Adjoining Districts.

Allusion has already been made to the Dover discovery, which has confirmed the views long held by many geologists, including the writer, as to the probable existence of a coal-field under south-eastern England, a discovery which may be very far-reaching in its effects. Another possible coal-area, which has given rise to a good deal of discussion lies in the country intervening between the Mendips and the Quantock Hills, and under the Bristol Channel to the south of the South Wales coal-field. The Mendip range, as has already been said, is a true anticlinal, the centre of the ridge being occupied by the Old Red Sandstone, from which the Mountain Limestone dips north-eastward in the direction of Bath, and south-westward towards Wells.

But although the Coal-measures are met with in their greatest thickness on the northern side of the Mendip hills, precluding the idea of this having been the margin of the basin in which they were originally deposited, there has hitherto been no evidence of their presence towards the south, unless we accept as such the carbonaceous beds of North Devon.

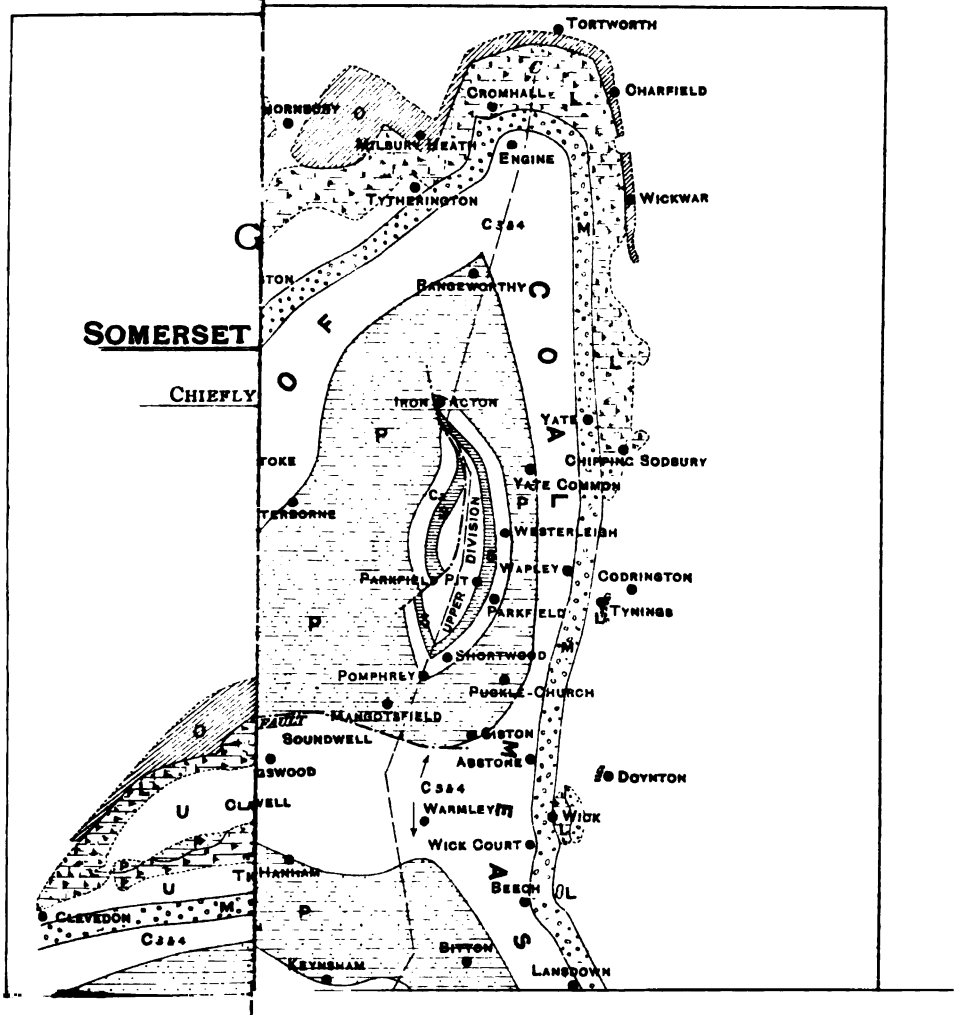
In the year 1815, the late Earl of Ilchester, acting under the advice of Mr. William Smith, put down a boring at Compton Dundon to discover coal. It began in the Keuper Marls, in which it was continued to a total depth of 519 feet, but without success.

Another unsuccessful trial was made a year or two ago, near Marston, on lands belonging to the Earl of Cork. It began in the Oxford Clay, and after sinking and boring to a depth of 600 feet, without getting through the Mesozoic rocks, the engineer abandoned the work.

There is nothing further to guide us until we reach the Quantock Hills, where there is a large exposed area of Devonian, forming the southern boundary of the district under consideration; and at Cannington Park, on the northern slope of the Quantocks, there are certain limestones believed to be of Carboniferous age.

Against the prospects in this southern area, three objections have been raised: (1) that as the Mountain Limestone on the southern slope of the Mendips, and the Devonian on the northern flank of the Quantocks are covered by Mesozoic rocks without any appearance of true Coal-measures between, coal does not exist there; (2) that as the rich Coal-measures of Somerset

To illustrate "the Somerset and Bristol Coal field" etc.



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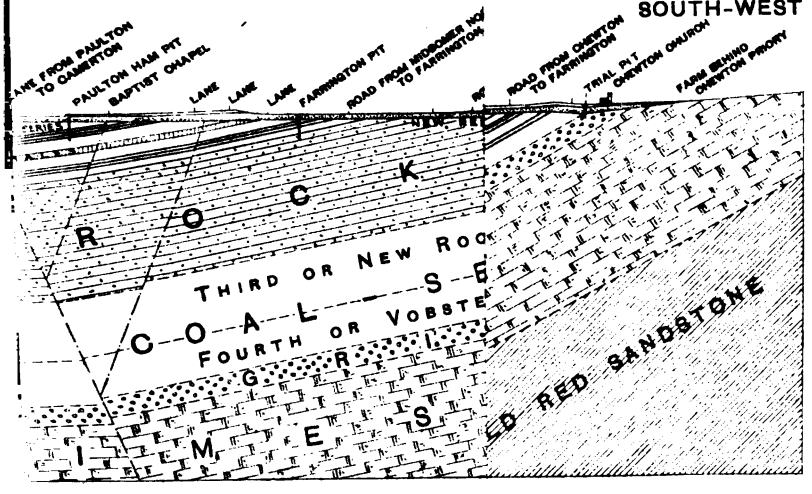
SOUTH-WEST



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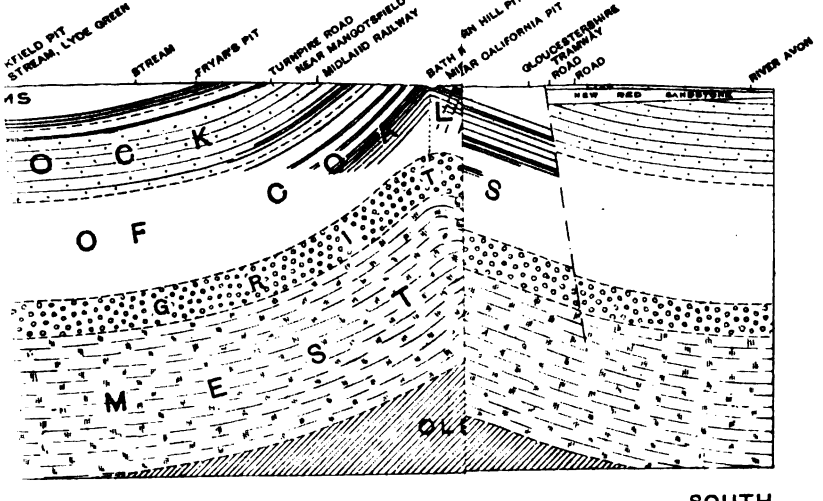

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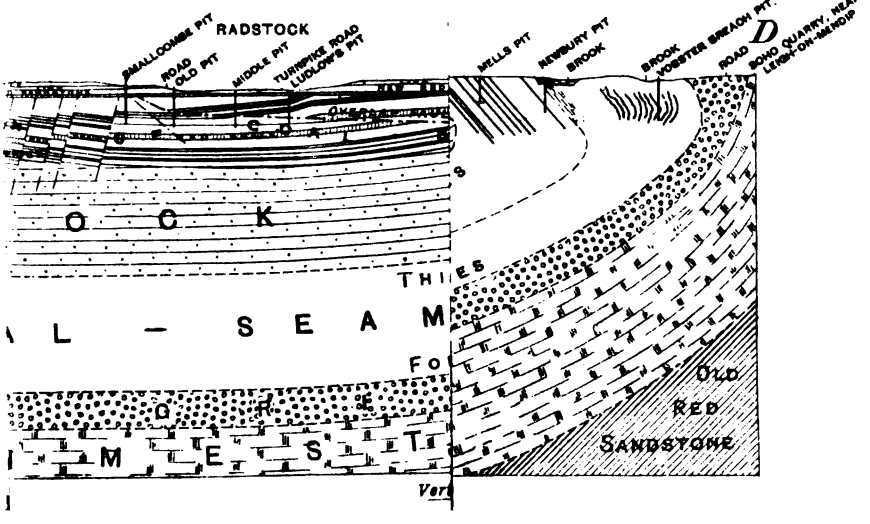

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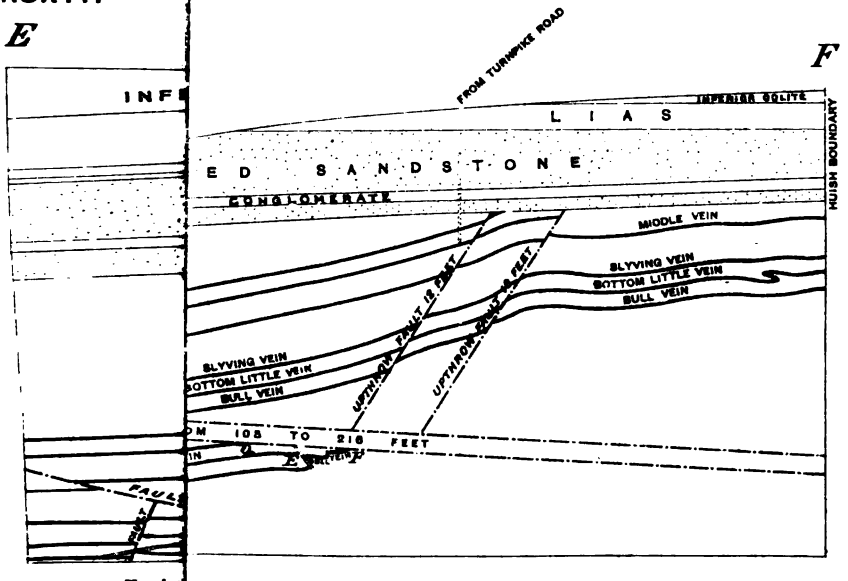
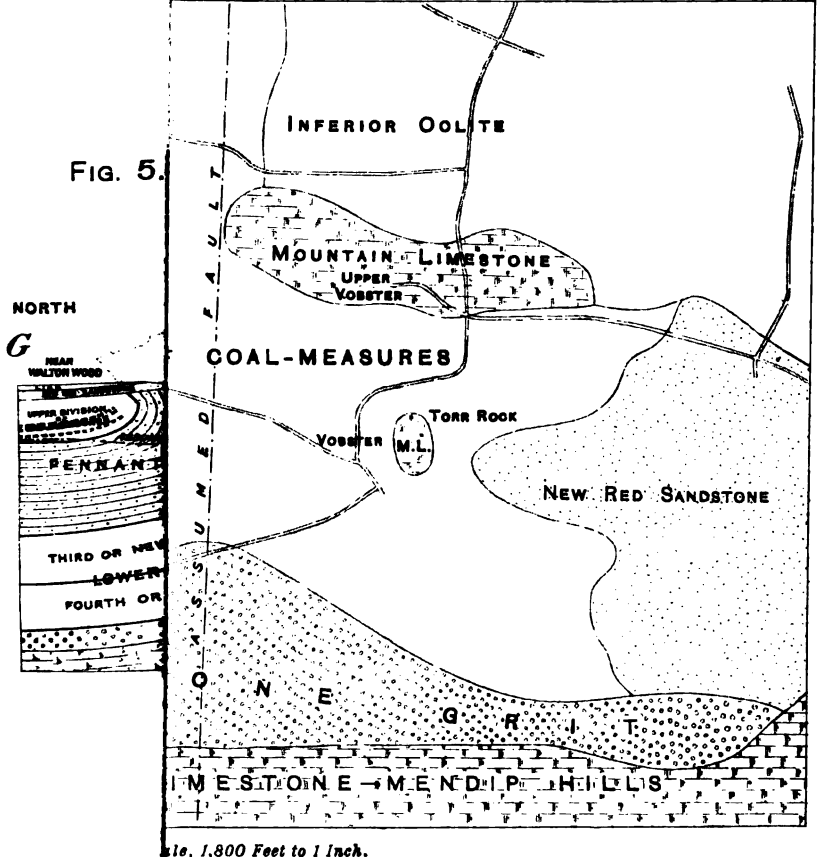


Horiz OF MOUNTAIN LIMESTONE AT VOBSTER AND LUCKINGTON.

FIG. 5.



ale, 1,800 Feet to 1 Inch.

degenerate southward and westward into the worthless Culm-measures of Devon, coal of any commercial value is not likely to be met with; and (3) that if Coal-measures exist at all, they lie at too great a depth to be considered workable. In the first of these objections there seems no force whatever: for in the known basin north of the Mendip hills the Mountain Limestone on their northern flank is for the most part immediately overlain by the Trias, but valuable coal exists there, nevertheless. As to the second objection, it may be remarked that if Coal-measures exist immediately south of the Mendips, they will hardly have lost the productive character which they exhibit immediately north of those hills; and in the opinion of Mr. Ussher and others the Culm-measures of Devon are not the equivalents of the true Coal-measures but of the Millstone Grit and Mountain Limestone, in an altered form. The third objection relating to the thickness of the Mesozoic rocks is one on which Mr. Charles Moore wrote with great ability, and on which he collected much useful information; but, in his estimate, he confessedly took "the greatest thickness of Secondary strata without the basin" as his guide, so that it is probably over, rather than under the mark, and even this estimate does not place the Coal-measures beyond a workable depth.

Another coal-area of less extent has within the last year or two been discovered under the Severn, between New Passage and Portskewit, but time will not permit the writer to describe this. He would only, in conclusion, express the hope that the facts he has stated as to the known and probable coal-areas of the South of England will make us feel more strongly than ever the importance of our national resources.

The CHAIRMAN (Mr. H. C. Peake) said that the members would all acknowledge their indebtedness to Mr. J. McMurtrie for his interesting paper. The Dover coal-field had been touched upon, and it was remarkable that, although some 10 or 12 years ago, the members had received a number of papers in reference to the development of that coal-field, its development was so slow.

Mr. T. FORSTER BROWN (Bristol), with regard to the Dover coal-field, said that it would be interesting to learn—assuming that there was a substantial Dover coal-field—whether the Coal-

measures proved there were those lying above or below the Pennant Rock, if they are above the Pennant Rock there was not much hope of the deeper coal-seams being proved and wrought, but if below the Pennant Rock of course it would be otherwise as the Pennant Series there would have disappeared.

In the Bristol coal-field, the Pennant Series owing to thickness and water-bearing strata had always been the great preventative to the rapid and economical development of the Lower Coal-measures which are the most productive part of the coal-field there and in the South Wales district. The Pennant Series in Bristol and Somerset was about three times as thick as in the Dean Forest and Welsh coal-fields. The economic result could be imagined from the fact that the output from 24 square miles in the Forest of Dean, was two-thirds of the output produced from 240 square miles in the Bristol district. The Upper Coal-measures comprized the Radstock series, which was more or less local and the Farrington, which came next, did not exist over so wide an area; but the Pennant Rock and the Lower Coal-measures were very wide and probably extended over the whole of the area of 240 square miles. It was wellknown that the Pennant measures were very heavily watered; and he would like to point out (and to hear the writer's views on the matter) that practically the whole of the outcrop of the Pennant Series north of the Kingswood anticlinal was exposed and therefore any openings or shafts would be very heavily watered. South of the Kingswood anticlinal, however, the measures were nearly all overlain by newer formations which ought to prevent the surface-drainage from penetrating into the Pennant Series, and consequently any attempt to sink through the Pennant Rock in the southern district ought to be a much drier operation than in the northern district. He agreed with Mr. McMurtrie as to the overlapping fault, which might have been produced in the following manner. If the Mendip hills had been raised gradually or suddenly at some point or other, resistance would be less than the force of the upheaval, and the measures being hard, the great thickness of Pennant rock being difficult to overcome, it had been broken off and turned over; but above that the Coal-measures were less strong and as the line of slip was approaching the surface and therefore the resistance became less, naturally continued pressure would end in producing an overthrust fault, instead of the overturning of the Pennant

measures, but the overturning of the Pennant measures nearer to the Mendip hills would produce an overthrust fault where the pressure was reduced. The Kingswood anticlinal appeared to afford facilities for getting at the Lower Coal-measures over a certain area at a comparatively shallow depth, and without sinking through water-bearing strata.

Mr. J. R. Bennett (Bedminster) said that the quality of the coals in the Farrington series, exposed in the northern part of the coal-field, was considerably better than elsewhere; but the seams were not so numerous, and there was not the same extent of coal. It was not quite correct to say that the Pennant Series was barren, and consisted only of a few thin seams. One of the great difficulties of working the coal-seams of the Pennant Series was that they were mostly so very thick; and it was not at all unusual to find seams, which for a considerable distance ranged from 20 to 30 feet in thickness; these were very difficult to work, because they were "bladders" of coal without a good roof and were composed almost entirely of not very profitable small coal. There was an immense supply of coal, which, sooner or later, would be developed, and one colliery, at present, was raising 2,000 tons per week from the Pennant Series; and with a market and more colliers it could readily produce 4,000 tons. Where exposed at the surface, the Pennant Series was heavily watered, and feeders of 1,000 gallons per minute were not at all uncommon. At the present moment, he was sinking a shaft, where the Pennant Series was covered with New Red Sandstone; and the feeder had not exceeded 1,000 gallons of water per hour. He was actually re-opening an old shaft, and some of the water might be bleeding from fissures in the workings, and the feeder might not be so large. It was possible that the number of coal-seams in the Lower Coal-measures had been over-estimated, as there was no single horizontal or vertical section covering the whole field, and he was inclined to think that seams similar in definition were put down as different seams, because they were met with under different conditions at different collieries.

He would not detract at all from the honour due to the late Mr. Handel Cossham, for his labours in connection with the Kingswood anticlinal; but he was personally inclined to think that Mr. Cossham's description of the fault in the neighbourhood of the anticlinal was perhaps only partially correct. He was in-

clined to think that instead of one fault, there was a series of anticlinals and synclinals. In some cases, where the apex had been denuded, faults on each side had been surmised, but he thought that a practical explanation would be found in the occurrence of a series of anticlinals and synclinals. With regard to the suggestion that the producing-causes of faults were still at work at Radstock, there was proof in this neighbourhood. Near the Clifton suspension-bridge, passing from the low-level station at Clifton, just through the first tunnel, only about 300 feet in length, a fault was exposed close by the river-wall, which maintained the bank of the river, and as a member of the Bristol Docks Committee, and having to do with the conservancy of the river, he could tell the members that the wall had to be periodically rebuilt because the fault-producing forces were still at work and over thrust the wall. The fault occurred at the junction of the Limestone and Millstone Grit. The dislocations, caused by many of these upheavals, were of so severe a nature that they had not only broken up the strata, but they had also broken the roof and floor of the coal-seams; and the cost of timbering sometimes reached 1s. per ton. In conclusion, he might say that in the midst of these great difficulties and aided by the able papers which appeared in the *Transactions* of The Institution of Mining Engineers, from time to time, colliery-owners in the Bristol district endeavoured to earn a modest but precarious living.

Mr. J. S. Martin (H.M. Inspector of Mines) said that few parts of the country presented greater difficulties and more contortions than the Bristol and Somerset coal-field. The output from this coal-field was about 1,500,000 tons in the year, as compared with 1,000,000 tons from the Forest of Dean where, although the seams are not very thick, they are more regular than in the Bristol and Somerset district. Being also nearer to the surface, and lying at a less inclination, the difficulties of working are not so great as in the coal-field under discussion. Unfortunately the Bristol and Somerset coal-field had been worked for many years, and much of the coal must now be obtained from great depths and from measures lying at very considerable angles, which he need scarcely say added greatly to the difficulties and expense of working. Colliery-owners in the Midland districts were able to work their coal at prices which, including long railway rates, allowed

them to compete with the Bristol district, which formerly was not the case. The pumping of water would no doubt in time become a very serious matter. Mining engineers would have to consider and overcome all these difficulties in order to produce coal at a moderate cost. He hoped that the coal-field might again be developed and bring renewed prosperity to the neighbourhood of Bristol.

The CHAIRMAN moved that a hearty vote of thanks be accorded to Mr. James McMurtrie for his valuable paper.

Mr. J. BATEY seconded the resolution, which was very cordially adopted.

Mr. JAMES MCMURTRIE acknowledged the compliment, and replying to the discussion, said that he agreed with Mr. T. Forster Brown that there was reason to believe that in the Somerset coal-field the quantity of water to be pumped in the Pennant Rock would be much less than in the Bristol and Forest of Dean coal-fields. He thought that a large area of the coal-field being covered with overlying formations, it would be more free from water than elsewhere. But the members should not forget that along the northern range of the Mendip hills there were extensive out-crops, from which considerable feeders of water might be expected. He thought it was possible that the number of coal-seams in the Lower Coal-measures had been over-estimated, but not to any considerable extent. Dr. Buckland, many years ago, obtained particulars from a great many pits in the southern basin, and he recorded the results in a form which was fairly reliable. In some portions it was absolutely correct; in other parts, where the seams had not been worked of recent years, there might be some doubt, but on the whole there would not be any great discrepancy; and for other districts Mr. Anstie had collected the information so carefully that there was not likely to be much discrepancy. The movement of the fault near the Clifton suspension-bridge was remarkable, and he hoped it would not make nervous people afraid that they were on the eve of some earth-convulsion in the neighbourhood of Bristol.

Mr. G. E. J. MCMURTRIE'S paper on "Methods of Working the Thin Coal-seams of the Bristol and Somerset Coal-field" was read as follows:—

METHODS OF WORKING THE THIN COAL-SEAMS OF THE BRISTOL AND SOMERSET COAL-FIELD.

By GEORGE E. J. McMURTRIE, Assoc.M.Inst.C.E.

Geology.—A previous paper having fully dealt with the somewhat complicated geology of this coal-field, it will only be necessary to refer to it in so far as it affects the methods of working.

In the Radstock district both the Radstock or top series, and the Farringdon or second series, are being extensively worked at many collieries, while the New Rock or third series, and the Vobster or fourth series are being worked at three collieries on the southern slope of the Mendip hills.

Radstock and Farringdon Series.—The usual method of working both the Radstock and Farringdon series is longwall, generally with a continuous face. Its application depends largely upon the direction and amount of the inclination, which varies from 3 to as much as 15 inches in the yard, and is generally from 5 to 7 inches per yard.

The main horse-roads are whenever possible driven *drift* or water-level, in order to ensure their drainage and to enable the horses to bring a fair journey of tubs.

The large number of both small and large faults, and the folding of the strata, have, however, entirely altered the regularity of the contour-lines, and the directions of the drift-roads therefore vary greatly even within small areas.

Rise stalls, locally called *topples*, are turned at intervals of 90 to 120 feet, at angles of 60 to 90 degrees with the drift-road, and the face is maintained on a slight curve, running down from the first turned topple to the leading drift-road.

Additional drift-roads are turned at intervals of 300 to 360 feet, and where the inclination is sufficient, it is customary to convert one of the topples cut off in each range of workings into an incline, generally with 3 rails above and 2 rails below the

partings, although in some cases 2 rails with self-acting points are used both above and below the parting or pass-bye (Fig. 1, Plate XV.).

It is not usual to work coal below the drift-road, but for various reasons *dipples* have frequently to be driven in such disturbed country; where possible ponies draw this coal up the dipples to the nearest incline-top or siding, and, where the dip is too great for this, small heavily-geared hand-winches are used.

Sometimes topples are turned at right-angles to the main drift-road at intervals of 300 feet and stalls or drift-roads out of these at intervals of 90 to 105 feet. The coal-face is still continuous, and kept on a gentle curve. This system would however appear to have few if any advantages over the previous one, and is consequently comparatively seldom adopted (Fig. 2, Plate XV.).

Where the seam is approximately level, it is possible to turn right-hand and left-hand drift-roads every 120 feet, at an angle of about 60 degrees and to concentrate fair quantities of coal.

In flat seams, or where the rise is moderate, youths generally run the tubs from the face of the roads to the nearest pass-bye, or to the gug-top, but usually, as soon as sufficient work is found, ponies partly or entirely replace the youths. At some collieries, however, it is considered better policy to employ lads to run the coal for long distances, and to dispense with ponies, as the additional wages thus earned are an inducement to the lads, and considerable economy is effected in the reduced size of road required to be made and maintained, and the consequently smaller quantity of rubbish sent to the surface. In cases of strikes this system has advantages, as there are few if any ponies to be fed; but obviously it leaves the owner at other times more dependent upon labour, whereas the tendency of to-day is to replace labour as far as possible.

Where the rise of the seam is moderate, it is usual in the topples to use a chain passing round a wheel, attached by a pair of jaws to a post at the top of the road. The roads are driven of the usual dimensions and are laid with but one road of rails: at the halfway a *turn-up* place is formed in the side of the road. On the tubs reaching this, the lad who has come down with the loaded tub stops it, he then throws the empty tub off the road and into the

turn-up, and, after pushing the loaded tub down below the turn-up he replaces the empty tub on the road and goes to the bottom with the full tub. Although apparently a primitive practice it works well.

Where the measures are too steep to use the tub, the *put* is taken down to the topple bottom instead, and the same haulage-system adopted. In such cases the coal is loaded into the tubs at the bottom of the topple.

The *put* is a box measuring 3 feet 6 inches by 1 foot 7 inches and 10 inches deep, with two wooden slides or runners beneath it, shod with iron, used in flat measures to convey the coal around the coal-face to the tub standing at the top of the road, and attached to the lad by a *guss*, consisting of a stout hemp rope, with a chain-and-hook attached to it; this is slipped over the head, and when in work rests upon the hips.

An improvement upon this system, would be after a time to use a single line of rails at the top and the bottom of the road, and to make a somewhat long pass-bye at half way, using a 2 feet wheel, with a brake attached, for the chain to pass round. In this case, it would be best to drive the road, where it is likely at some time to form the pass-bye, of extra width; as the additional cost of this would be recovered in the reduced rate for jigging the coal, as compared with twin-work or running.

Gugs or inclines are largely used wherever possible, and on account of the small quantities than can be concentrated, and of the many faults, where driven in solid strata, frequently rise 1 foot to the yard. If driven in the seam, they generally rise about 6 inches per yard. In important cases they are laid with 2 roads from the top to the bottom, but more generally with 3 rails above partings and two rails below.

Ropes are used on the permanent gugs, and chains on the topples, on account of the latter permitting of short lengths of chain being added as the topple goes forward, by inserting rivetted links. Bridge-rails are used wherever the tub goes, but in the coal-face, the put is drawn or pushed on the hard bottom of the seam.

Formerly wooden *crease* was used in put-topples, but with their general abolition it has now largely disappeared. Its section is shewn in Fig. 3 (Plate XV.), and the two sides were braced together at intervals.

Boards called *slides*, 1 inch or so thick, and 5½ feet by 1¼ feet, with eyes attached at either end, are used to bring out the large lumps of coal from the face. In some cases, such lumps weigh as much as 15 cwts.

In all the seams of the Radstock series, the coal is wrought either over or under the seam, to prevent the waste due to cutting in the seam. Exceptions, occur, however, where there is nothing suitable over or under the coal in which to hole, and it must be cut in the seam itself; a very real disadvantage in such seams, especially as they are primarily house-coals. Cutting in the coal is more common on the Farringdon or second series, the seams of which vary much in section and quality in short distances: much of this coal, however, is used for manufacturing and steam purposes.

There is nothing unusual in the methods of timbering either at the coal-face or on the roads. Where there is more rubbish produced than is required to fill the gob, 2 rows of timber are maintained, one immediately in front of the gob, and the other between it and the face. In seams producing less rubbish, 3 rows of timber are set, and the back row is drawn, as a fresh one is put up.

In seams producing little rubbish, a number of stone pack-walls, locally called *tumps*, are carried forward in the gob, with spaces or bays between. Nine feet pack-walls are carried on either side of all roads, built with stone principally got from ripping the roads.

At certain collieries, systematic timber-drawing is carried out in seams producing sufficient rubbish to fill the head. In seams producing less dirt, tumping has to be resorted to in order to do this, and in that case it is open to question whether any direct return is obtained.

In thin seams, having strong roofs, with nothing suitable over or under the coal to hole in, and which consequently produce no rubbish beyond what is produced in the ripping of the topples and drift-roads, little can be done in this way, as cogging is the only expedient, and this will certainly yield no return to the colliery-owner; unless it be in the shape of additional large coal.

It has always appeared to the writer unfortunate that the in-

clination of the strata has hitherto prevented the conveyance of rubbish from a seam producing more than is required to fill the goaf, to a seam producing less than is needed. Such an arrangement would materially add to the output by replacing rubbish with coal.

New Rock and Vobster Series.—Probably the most interesting part of the Radstock district comprises the workings on the New Rock and Vobster series, owing to their steep inclinations, and the unusual natural difficulties met with. These difficulties were created by the rise of the Mendip hills, which forced back the seams to an upright position, and even in places has bent them right over, so that in sinking the Vobster shaft the same seams were passed through twice, while at Edford, seams are to-day being worked, the roofs of which gradually fold over and within a short distance become the floor of the seam.

At the New Rock colliery, the rise of the seams is about 28 to 30 degrees, and two coal-seams are worked, namely, the Small Coal and the Garden Course. The system of working again is longwall, but the face is no longer continuous. A drift-road having been driven, gugs 7 feet wide and 5 feet high are set away at right-angles to it, every 180 feet, having 90 feet on either side of them, and separated from the next gug by a step varying from 15 to 24 feet in depth, along which an air-way is maintained.

On account of the steep inclination, in place of making long continuous inclines, they limit their length to 300 feet, and drive a short drift of 15 feet or so, alternately to the right or left-hand, and set away another gug; thus there may be 3 or 4 gugs one above the other. To each of these gugs, there are 4 hewers or getters, and two boys, who fill, wagon and jig the coal (Fig. 4, Plate XV.). It is not unusual in these faces to place ladders on the floor to provide a footing for the colliers.

At this colliery, no ponies are used underground, but lads run the coal to the shaft from the outside-gug of the district. Beyond this point, puts, 3 feet long, 1 foot 5 inches wide, and 8 inches deep are used. The gugs are laid with 2 roads of wooden crease, and the coal is let down by a light drum and chain. As the drum-frame is moved forward, and the chains lengthened, every 6 feet, it is not fixed as permanently as usual. The two uprights are set

into the ground, the head-piece fastened at the top, and strengthened by two stout props, on either side. The usual shaft-carriages are without apparently any good reason, except possibly economy of time, replaced by hooks screwed into the frame (Figs. 5 and 6, Plate XV.).

Bogies or *mutes*, 6 feet long and 1¾ feet wide, with a shallow rail round them, and which carry two puts, are used to take the coal from the gug-bottom to the tub-stage, where it is tipped over and loaded (Fig. 7, Plate XV.).

Of late years in some cases, tubs have been jigged to the face of the gug, and only the puts or slides are used along the face.

At Edford colliery, however, much of the coal is vertical or upright. The three coal-seams worked, namely, the Standing Coal, Main Coal and Perrink, having sections of fully 4 feet, permit of the adoption of a modified form of longwall.

In both the Standing and Main coal-seams, a slice, 9 to 10 feet high and the width of the seam, is taken on the level, and secured by settings, consisting of two uprights and a stout cap or crown-tree; protecting these are *cleads* or poles, 4 to 5 inches in diameter, running from cap to cap and prop to prop, and behind these is placed brushwood, locally termed *ricewood* (Fig. 8, Plate XV.). Above this road or working-place, are two or three others (Fig. 9, Plate XV.).

In each case they are protected by the same method of timbering, and the props or uprights of the upper place are let into the crowntree of the lower.

A certain amount of small dirt is placed upon the floor in the upper places, upon which the rails, which are of a very light section, are laid. This serves also to keep the air up to the face, for the lower place is generally made the intake and the top place the return air-way, and as these seams produce much gas considerable care is necessary.

In cases of specially bad roof, *tangers* are used; these are stout cleads or small poles, pushed over the crowntree, and projecting beyond it and let into the coal-face. They are made fast by wedges driven in behind the setting. The following setting makes this arrangement permanent.

In the Perrink seam, the coal is worked to the rise by longwall,

but it is a matter of great difficulty, and frequently they are compelled to fall back upon the method just described.

Crease-holes or chute-holes are turned every 150 feet, sometimes cuts replace these, and are considered by some preferable to the former.

The system of timbering is most complicated, and looking up at a coal-face is very much like looking down into a deep cutting for water or sewage-pipes, in which the sides are heavy and have to be frequently supported by cross-timbers fixed against slabbing up either side. This largely describes the system of timbering adopted, with the exception that foot-lids are only set in tender ground, while in other cases the props are stamped in, 3 feet apart in both directions. To further secure the face, cogs, 12 feet high, are set at intervals and consist of hollow frames, 5 to 6 feet square, built up of pairs of old timbers that regularly cross one another.

Planks are laid, along the face-props, on which the men work, and the tender coal is cut out, no holing whatever being done in any of these seams. Indeed the seams are so very tender that holing beneath the seam would not add to the large coal produced.

These seams are very irregular, and faults frequently throw the coal away to the right-hand or left-hand, while patches of dead-ground are frequently found.

In the vertical workings, where the coal is worked off in 10 feet slices, the lowest road should be well laid with light steel rails; and the coal from the higher places is either dropped through vertical cuts or chutes to the tubs on this road, (this system being favoured here), or brought down slants to the bottom-road. Cuts are secured with wooden chuting, 3 feet square, morticed at the corners, and with regulating slides at the bottom. Slants are generally laid with wooden crease, and the puts, here termed *boxes* and which measure 2 feet 9 inches in length, by 1 foot 6 inches in width and 1 foot 6 inches in height, are dragged to the face. Boxes are lowered down these cuts by means of a chain secured to a prop at the top. A double hook is slipped over the back of the box, and the chain is passed through the other end of the hook, and under the box to its lower end, where the lad lets it out as required.

In the longwall workings, the arrangements for getting the coal to the drift-road are very similar, sometimes chutes are used, and sometimes the roads are laid with wooden crease.

Lads run the coal in stages from near the coal-face to the pit-bottom, a light iron frame with 2 pairs of wheels being placed under the boxes, and tubs are dispensed with.

In place of sidings, there is a curious arrangement of meeting-places or stages covered with timber; the one lad runs his full box to a stage, pulls it off his frame and on to the stage, and returns to the face with an empty box. A second lad then pulls the full box of the first boy over the stage on to his frame and goes out to the pit-bottom with it. The last stage is often done on double carriages, 5½ feet long, similar to light trolleys, and carrying two boxes, each of which holds 2½ cwts.

No horses or ponies are used in this pit. The cages also are not fitted with rails, the boxes being pushed into them on their slides.

The pressure on these workings is exceptionally heavy, and roads 8 feet high rapidly come down to 3½ or 4 feet, necessitating constant repairs and very heavy timbering. The seams themselves, however, produce so little rubbish, and their inclination is so great that the goaf largely remains unfilled.

At the neighbouring Newbury collieries, where the inclination is not so great, and the coal-seams are more regular, the long-wall system is adopted, with 90 to 132 feet between the topples, which go up 300 feet, and are then cut off by fresh drift-roads. The face is not continuous, one gug being 15 feet in advance of the next, with air-ways maintained along the steps, and 45 to 66 feet taken out on either side (Fig. 10, Plate XV.). The coal is worked on the level, 9 to 10 feet slices being taken right and left from the topples.

The roof, where sufficiently good, is secured by 2 rows of ordinary props and lids, and great care is taken to well stow the head, as this greatly helps it to stand. Where bad, the face has to be secured by settings of two props, and a cap or crowntree; and where very bad, 10 feet bars with 3 props are set at the face.

The topples in the first range of workings are made 7 feet wide and 6 feet high, and laid with wooden crease, the puts being lowered by a chain passed round a prop at the top. The coal is tipped up on the stage at the bottom, and passed down chutes into the tub below.

When this range is worked out, one topple is made into a

self-acting incline, a suitable drum erected, and the tub is jigged to the higher level: the second range of workings being carried up as before.

In some cases, the coal is sent down the topples in chutes to the stages below. Horses take the coal to the pit-bottom from the stages or from the gug-bottoms.

A thin slice of coal is sometimes left on the lower side of the road to keep back the dirt, and very little coal is got below the level-road.

All roads are secured as at Edford colliery by settings, with cleads or polings over the bars and behind the props, with brushwood behind these again.

The pressure of the ground at these collieries is very great, and large roads speedily become crushed and small: the timbering is consequently of a specially heavy and expensive character.

The Vobster collieries, which formerly worked several of the seams of the Vobster series, and were situated just at the angle where the seams have been thrust over, worked them on very similar lines.

Bristol and Parkfield District.—In the Bristol and Parkfield districts, the system of working is again longwall, but on account of the more tender nature of the roofs the face is generally not continuous. The Coalpit Heath and Oldland Common collieries, however, form exceptions, and work on the pillar-and-stall system. Formerly, this system was also adopted at the Golden Valley colliery, but longwall has now replaced it.

In the Nailsea basin, pillar-and-stall was also worked, but the large amount of dead-ground met with, the great quantity of water that had to be pumped, and the large proportion of small coal produced, brought about the closing of all the collieries in this part.

The methods of working are very similar to those adopted in the Radstock district. Level-roads having been driven, hatchings or cross-gates are turned to the rise every 300 feet, at an angle of 60 degrees, and stall-roads set away, on the level, out of these every 60 feet, having the coal-face on the line of full dip. Or hatchings are turned out of and at right-angles to the level-road, every 120 feet, and the stall-roads are dispensed with. These

hatchings are separated by 15 feet steps, and are cut off every 240 to 360 feet by fresh levels.

When working coal that lies to the deep of the shaft, and that has to be won by means of engine-planes, two or three endings are driven to the full dip, and out of these pairs of main levels, or a main level and a deep cross-cut, are set away every 240 to 360 feet, and the coal is worked to the rise in one of the ways just described (Figs. 11 and 12, Plate XV.).

In certain seams at the Hanham and Kingswood collieries the hatchings could only be driven up 120 to 150 feet, with 36 feet between the hatchings, or between the main levels and deep cross-cuts.

A system was some years ago introduced at the Kingswood collieries, of working the coal to the dip instead of the rise, in order to dispose more readily of the rubbish produced by road-making, falls, etc., instead of sending it up the pit to cover valuable agricultural land, and reduce the output by preventing coal from being wound; and also to do away with the ripping consequent on taking horses to the face. In thin seams, enough rubbish is produced to fill the goaf, but in seams of 3 to 4 feet this is not always the case. In addition, this system is supposed to help the ventilation, as the air works to the rise.

A level or pair of levels was first driven, and panels, 360 feet long by 450 feet to the dip, set out. A small haulage-engine was next fixed at 180 feet along the low level and on the rise side of it, with, we will suppose, cylinders 8 inches in diameter by 1 foot stroke, and a drum $2\frac{1}{2}$ feet in diameter, geared 5 to 1, and with a $\frac{5}{8}$ inch steel rope 600 feet long. This engine was mounted on a wrought-iron frame, fitted with wheels to the gauge of the underground roads, so as to be easily moved, and measuring $6\frac{1}{2}$ feet long, by 4 feet high, by 4 feet wide. Compressed air was supplied at a pressure of 40 pounds per square inch. A dip-heading was then driven as shewn in Fig. 13 (Plate XV.), 7 feet wide, with 21 feet of coal taken out on either side, and an airway carried at each end. At 30 feet down, flank-headings are turned, which, after gaining a face of 48 feet, are driven parallel to the main dip-heading, thus giving a face of 144 feet, or three faces of 48 feet, with 15 feet steps between each. Out of the flank-headings, levels dipping

towards the face are driven every 48 feet, and 27 feet of coal are worked to the rise, and 15 feet to the dip.

Three dip-headings, and two levels out of each flank-heading, with 4 men to each working-face, would yield 100 tons per shift of 8 hours.

A great objection to this system would be the presence of water in the face, which must be either hauled or pumped. Its success, too, must depend upon the regular dip of the strata, and freedom from faults, particularly from upthrow faults.

When the dip exceeds 30 degrees, and the floor is slippery, it is difficult to build pack-walls; two props are therefore set at right angles to the dip, and a little distance apart, and chocks are set up against the props on loose earth, the walls are carried up vertically to the roof, and loose stones are packed behind. The chock thus forms a temporary support for the foot of the pack-wall until the weight tightens the pack-wall, when they are withdrawn.

Later, the following system of working the coal to the rise was adopted on inclinations of 45 to 55 degrees. From the engine-plane a pair of main-levels, or a main-level and an air-way, were driven, and rise-hatchings set away to the full rise every 1,200 feet. Level-heads were then turned out of these to the right-hand and left-hand every 54 feet, and the coal-face kept at an angle of about 30 to 40 degrees (Fig. 14, Plate XV.). To extend the rise-hatchings, a small place is driven up to the full rise on either side of the main-hatchings, and the coal is loaded into hods or puts, and lowered to the level-head below, by means of a chain passed round a prop at the face. As soon as these places have gone a sufficient distance, the wheel and frame are moved forward at a week-end and another pair of level-heads is ready for starting. A similar road is occasionally driven up should a serious fall occur in a coal-face.

The coal was lowered from the different level-heads to the level below by means of a balance-platform, with the weight travelling beneath the road-way so as to reduce to a minimum the width of road-way to be maintained; the speed of this platform was regulated by a brake.

By an arrangement, the platform was so contrived that, in spite of slight variations in the gradient of the road, the level of

the coal-tub was maintained. Such a carriage would work for a distance of 900 feet, after which the weight of rope was found too great, and it would be necessary to substitute a larger platform capable of carrying 2 tubs, and to increase the balance-weight.

When working coal to the deep of the shaft, the platform was abandoned, and, if the inclination did not exceed 45 degrees, planes were driven full deep-ways, and the tubs picked up from the different level-heads by a main-rope system of haulage. Partings were put in opposite each level, and sufficient flat-sheets laid to allow the empty tub to be shunted; in this case, the apex of the triangle formed the deep corner. Should, however, the inclination exceed 45 degrees, planes were driven at such an angle as would ensure the inclinations not exceeding 45 degrees.

The coal lying between a couple of such planes was troublesome to get, on account of the very acute angle that they formed with the levels. The difficulty was overcome by forming these back-over levels 108 to 120 feet apart, and driving up frequent small hatchings at right-angles to the back-over levels. The coal was brought down these hatchings, which were kept full to reduce breakage, and the timber taken to the men working in the lower levels from a higher one (Fig. 15, Plate XV.).

A very similar arrangement is in use at the Ashton Vale collieries for inclinations of 20 to 80 degrees, but in this case the balance-carriage runs on a parallel road, and there is a separate carriage to every hatching. The coal-face also is on the line of strike, in place of the line of dip, and additional hatchings, driven at right-angles with the level-road, replace the level-heads.

The system adopted at Coalpit Heath colliery, in both the Hard and High coal-seams, is as follows:—Main-levels, 9 feet wide, are driven 300 feet apart, and, in the Hard seam hatchings are driven to the full rise every 300 feet, and headings are set away on the level out of these every 66 feet. Hatchings are driven 33 feet wide with a stone-pack wall on one side, leaving a road 8 or 9 feet wide. Headings are started 18 feet wide and widen to the deep to 33 feet, which is carried through to the gob of the next hatching, an 8 or 9 feet road being maintained against the coal, with a pack-wall on the low side made from the rubbish got in ripping the road.

On reaching the back of the heading, they cut through the 33 feet pillar above to the gob of the upper heading, generally, 12 feet from the end. Some time after, this pillar is brought back to its hatching, and the small pillar or stook of coal, 12 feet by 33 feet, is got from the next hatching by putting a hole through its pack-wall (Fig. 16, Plate XV.).

A 33 feet pillar is left against both sides of all main-levels.

In their High seam, a similar system is adopted, with the exception that the headings are driven every 39 feet, 24 feet being taken inward and 15 feet brought back. If the roof is bad, headings are started 9 feet wide and widened to 24 feet in a distance of 15 feet. The dip of these measures varies from 1 in 3 to nearly flat.

No explosive is permitted in getting these seams, wedges alone being used.

At the neighbouring Eggs Hill colliery, the Hard and Black seams are worked by longwall to the dip. Levels are turned out of the engine-plane every 210 to 240 feet, and hatchings are driven to the full rise every 90 feet, and go through to the broken of the upper level.

At the Oldland Common colliery, California pit, working the Millgrit, Rag, Buff and Parrot seams, the following system is adopted:—Straights or level-roads, 6 to 12 feet wide, are driven, and hatchings set away to the rise, 6 to 12 feet wide, and 72 feet apart; making the pillars 60 feet square.

After the narrow work has been driven, the pillars are got thus:—A 9 feet hatching is driven through the middle of the pillar, splitting it into two parts. A 9 feet straight is then driven through the outer of these, dividing it also into two parts. A second hatching is then driven through the upper of these parts, dividing it again into two parts, and a straight, A, is also put through the outer one of the two parts, dividing it into two small pillars, each 9 feet square, which are robbed as far as possible.

A straight, B, is then driven through the other half of the pillar, dividing it and leaving two similar pillars, 9 feet square, which again are robbed as far as possible.

The lower quarter of the pillar is worked off in the same way, and then the other half of the pillar is similarly treated (Fig. 17, Plate XV.).

If the roof is good, little coal is lost, but it is never completely got. Where the roof is bad, straights and hatchings are driven 6 to 8 feet wide, and if the top be specially good, 12 to 15 feet wide.

The inclination of these seams is 10 to 12 inches to the yard.

The means adopted for conveying the coal from the coal-face to the shaft, in the Bristol and Parkfield districts, are also very similar to those in use in the Radstock district. At the Kingswood collieries, where the inclination is under 1 in 2½, the tub is taken to the face in both the Great and Five coal-seams, but hods are used on the Two-feet seam. Both trams and hods are lowered down the hatchings to the main-levels, by a chain passed two or three times round a prop at the coal-face and the empty tubs are pulled or pushed up to the coal-face. In the steep pitching, as already described, the tubs or trams are taken to the face in all three seams.

At Ashton Vale colliery, on inclinations of 10 degrees to 20 degrees, the hatchings are arranged as inclines, with two roads and a small jig-pulley and brake, which take the tubs or trams to the coal-face. In their thinner seams, puts or hudges are jigged, and the coal loaded into trams on stages at the bottom. This arrangement is also in use at the Dean Lane and Hanham collieries for lowering the trams down the hatchings to the main-level, and one or more hatchings are made into a main incline, and carried forward as each range of hatchings is cut off by a fresh level-road.

At many collieries, however, with a steep dip, the tubs are taken only to the face of the drift and dip-roads, and to the bottom of the hatchings, and the coal is jigged in hods or puts from the coal-face to stages at the bottom. Such gugs are driven 6 feet high and 7 feet wide, and laid with two roads of wooden crease.

Hods and puts vary in size, but are generally about 3 feet long, 2 feet wide and 11 inches deep.

The tubs or trams are either taken by horses or run by lads to the engine-plane, or possibly to the shaft-bottom.

Occasionally, a chain is fastened to a post at the face, and the same arrangement of double hook is used to lower the puts as at Edford colliery.

Where the inclination of the seam is moderate, as at Coalpit Heath collieries and the seams are somewhat thicker, horses are generally used to bring the trams from the coal-faces to the engine-plane. In the High seam this is almost invariably the case, shafts

or limbers being used on the steeper parts. Horses are also largely used in the High seam. Hods or puts are therefore not used on the High seam, and very rarely on the Hard seam, except to bring back the pillars. The coal is then thrown up to the tram on the road, and the breakage caused by double loading is said to be prevented.

Some hand-tramming is however done, and, where trams have to be lowered down hatchings to the level below, chains are used; built up in 12 feet lengths, connected together with C links, and passed round a small ribbed pulley, fastened into a prop at the top by a pair of jaws, which have a very ingenious arrangement of levers, causing the jaws to grip the outside of the pulley and to act as a brake. The hatchings are laid with two roads of steel-rails.

In the thicker seams of the Bristol coal-field, it is usual to take the tram along the face, and then hods or puts are used only in the face of the level-roads. When the distance between hatchings is very little the coal is often thrown to the tram.

Steam Haulage.—Haulage by steam-power has of late years been greatly extended in both the Radstock and Bristol districts, either on the main-and-tail, or main rope systems. The nature of many of the roofs and the thinness of the seams, with the consequent expense of making and maintaining good double roads, preclude the general adoption of endless-rope haulage; although at one colliery, with an exceptionally good roof, an endless-rope is now being put down.

The faulty character of the district, the frequent changes in the strike of the seams, due to this and other causes, necessitate frequent bends on main-roads, which are here largely driven water-level; the thinness of the seams, and the consequent inability to concentrate large tonnages at any one point, are reasons why steam-haulage is not more largely adopted. In spite of these natural difficulties, however, haulage by steam and occasionally by compressed air, is largely adopted in bringing coal long distances on the level, and almost entirely in working coal lying to the deep of the shaft; although on account of these difficulties, the usual powerful single haulage-plant has generally to be replaced by two or three smaller engines, bringing smaller quantities from as many districts or directions.

Some excellent arrangements of self-acting inclines, with

branches to win the different seams, are to be seen in these districts, which concentrate considerable quantities of coal at one or two points; but these are generally combined with mechanical haulage.

Holing or Getting.—In these thin seams it is very seldom that a seam of coal is got in the coal itself, it is almost invariably holed in a bed of under-earth, or, if this be absent, in a band of shale in or over the seam. Occasionally when a seam of clean coal is wrought, with nothing over or under, the coal itself has to be cut, and much additional small coal is made. On the steep workings of Edford colliery, however, all the coal has to be scalloped, and in certain other cases the thicker coal-seams are holed in the bottom of the seam.

System of Timbering.—The different methods of securing the coal-faces have already been described, and the general system of timbering the roads consists in the setting of an ordinary crown-tree or cap and two uprights, with cleads, polings or laggings, running from cap to cap, where required. At the New Rock colliery, however, where the inclination is 28 to 30 degrees, it is also found necessary to maintain cleads behind the posts on the high side of the level-roads and in the gugs; and on the levels the cap is cut into the roof on the low side, nothing being taken out below the level, and the floor is levelled by bedding up the low-side. The special timbering of the Edford colliery has been previously referred to.

Explosives.—Since the coal-dust explosions at Camerton and Timsbury collieries, much greater care has been exercised in the use of explosives. For many years, the use of loose powder was permitted in this district. The greater convenience of compressed cartridges, however, ended this practice. To-day, at many collieries, no explosive whatever is allowed to be used in the coal; and at others, where odd shots are necessary, officials are specially appointed to fire such shots.

Shots, on the roads, are generally fired during the afternoon shift by a specially appointed shot-firer, blasting-powder being used at some collieries within 30 feet of the coal-face, and roburite or some safety-explosive elsewhere; while at several collieries

safety-explosives are alone permitted to be used. Formerly was the custom to supply colliers free with any powder that th required; the newer practice, by which at many collieries t colliers only drill the holes, is stated to have affected an econom in the number of holes put in and the powder used: althou additional labour is required for the shot-firing.

Watering of Roads.—Systematic watering of the roads is al carried out at many collieries.

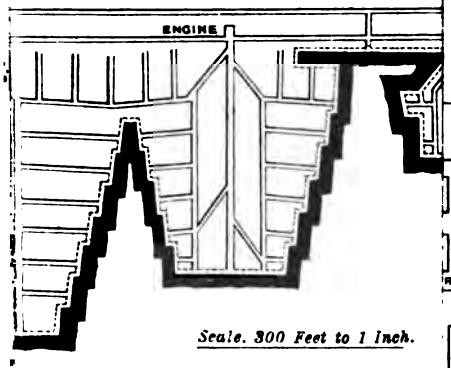
Rubbish produced.—Naturally the thin seams worked produ much rubbish from the holing and in the construction of road although roads are reduced in size as they approach the point whe they are to be cut off, and roads are cut off before they are expecte to need repairs or a second ripping. The roofs of the district a as a rule not strong, especially in the Vobster series. Seams 24 to 26 inches, however, generally hold most of, if not all of, th rubbish produced, but seams of 13 to 16 inches will not do s although great care is taken to thoroughly stow the gob, and a roads are filled as they are cut off. The excess, amounting i some cases to 25 or 30 per cent. of the total output, has to be sen to the surface, to cover valuable land.

The extremely faulted nature of the district also adds largely to the number of stone-branches required, and to the rubbish produced.

Pumping required.—While this cannot as a whole be considered a heavily watered district, yet there are few collieries without feeders of 200 to 500 gallons per minute, and a good pumping-plant, generally of the Cornish type. In the Radstock district, the New Red Sandstone is as usual heavily watered, and has at its base a water-tight bed. In the older and smaller pits, this water was kept back by coffering of Lias stone and hydraulic Lias lime.

Little additional water is met with down to the base of the second or Farringdon series; at the Radstock collieries three small feeders of salt-water were met with in sinking from the one series to the other, namely, 90 gallons per hour at 1,350 feet, 500 gallons per hour at 1,380 feet, and 100 gallons per hour at 1,692 feet. Analysis proved that this water also contained calcium chloride, calcium carbonate, potassium chloride, lithium and iron.

Fig. 13.



Scale. 300 Feet to 1 Inch.

Fig. 12.

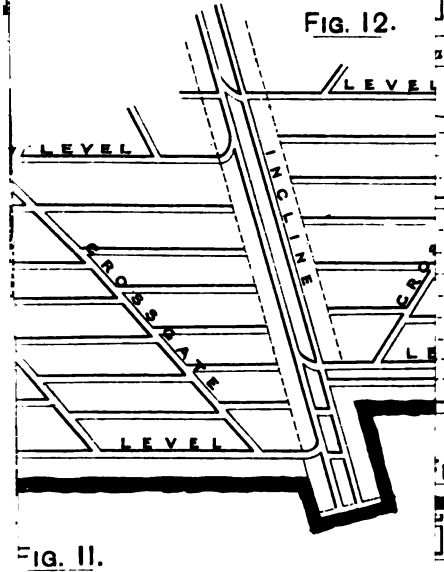
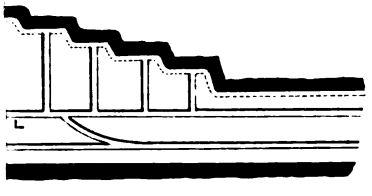


Fig. 11.

Scale. 300 Feet to 1 Inch.



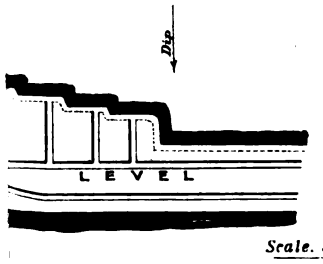
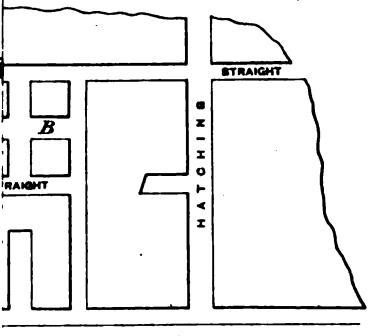
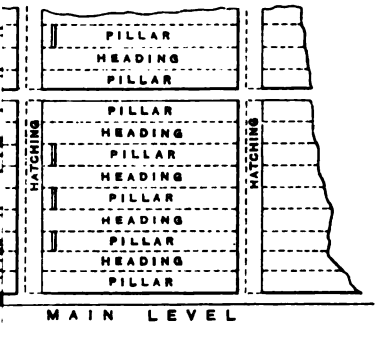


Fig. 17.

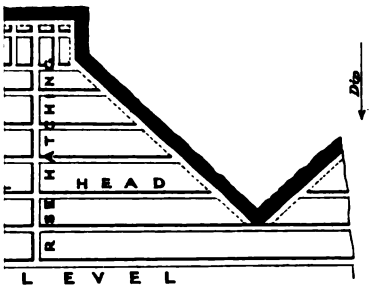


ale, 50 Feet to 1 Inch

Fig. 16.



ig. 14.



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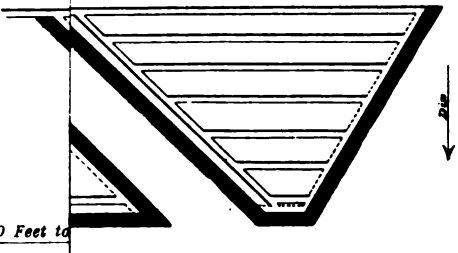


Scale. 300 Feet to

The Pennant Rock is stated to contain much water, though this would not appear to be always the case. Below the Pennant Rock little water is met with.

The absence or presence of cover on the Coal-measures has much to do with the quantity of water to be dealt with, and the Radstock district is greatly blessed in this way.

Ventilation.—The Radstock, Farringdon and New Rock series of seams are entirely free from gas, and are worked with naked lights in the shape of candles. The Vobster series, however, is fiery, and is worked with safety-lamps at the Vobster, Edford and Newbury collieries. The gas at Newbury collieries burns with a very white flame, and probably contains some carbon monoxide.

In the Bristol district, the Bedminster and Ashton seams are fiery. The seams at present worked in the Parkfield basin are free from gas.

Generally the ventilation in these districts is produced by furnaces, fed by splits of fresh air if the colliery be fiery; at some collieries however fans are preferred.

Output.—It may interest members to know that to produce a daily output of 450 to 500 tons from these thin seams, 2½ miles of face-room and 15 miles of road are required. This will also afford some idea of the cost of timber.

Prof. H. Louis (Newcastle-upon-Tyne) asked whether there was anything in the history of the district to indicate that the method of working which had been described—especially in the vertical seams—was in any way due to German influence. The term "rice-wood" was synonymous with the German term, and the method of working was very similar to theirs.

Mr. James McMurtrie (Radstock) said that he had no reason to think that the origin of this method of working was at all connected with Germany. "Like conditions begat like contrivances," and the same vertical and contorted seams which were worked in Westphalia had led to similar contrivances to overcome those difficulties. It was remarkable that the word "rice" was used not only in Germany, but it was in common use in Scotland by the woodmen.

Mr. M. WALTON BROWN (Newcastle-upon-Tyne) said that "rice-wood" was applied to the branches of trees, used in making roadways across boggy ground in the Cleveland district.

Mr. S. F. WALKER (London) asked whether coal-cutters could not be applied to the working of the thin seams of this district.

Mr. J. S. MARTIN (H.M. Inspector of Mines) said that coal-cutting machines were used in one of the Monmouthshire collieries he understood with advantageous results. Fire-damp was unknown and naked lights were used in the collieries of the Radstock district, so that electrical coal-cutters could be safely introduced.

Mr. JAMES MCMURTRIE stated that coal-cutting machines had never been used in the Bristol district. One was purchased and brought to a colliery some years ago, but it had never been used. Some of the seams were worked as thin as 12 inches, and the holing was made in shale, and the total thickness of the coal and the holing would not exceed 15 or 16 inches. The longwall system of working, described by his son in his paper, was probably one of the earliest examples of longwall working anywhere in the country. Many years before South Wales attempted to work coal on the longwall system, it had been prevalent in Somerset, and he could not ascertain that any other system had prevailed, although some of the pits had been at work for over 100 years. The pillar-and-stall method had been attempted at a colliery, but it was soon abandoned.

Mr. J. S. MARTIN remarked that although some of the Radstock seams were only 12 inches thick, they were not all so thin, and a trial might prove the advantages of using coal-cutting machines.

Mr. H. ST. JOHN DURNFORD (Pontefract) said he had seen coal-cutting machines working in seams only 16 inches thick and the cut was made to a depth of 4½ feet. The height occupied by the machine was 15½ inches. If coal-cutting machinery would produce coal cheaply, the future of this coal-field would in a great measure depend on its introduction. He thought that coal-cutting machinery was peculiarly adapted to the working of thin seams, and in years to come he believed that many such machines would be used.

Mr. G. E. J. McMurtrie, who had been absent during the reading and discussion of his paper, said that there should be a future in these districts for the machine coal-cutter. Several of the seams were very thin, but some of these very thin seams were difficult and most costly to work, owing to their section and the hard nature of the holing. It therefore appeared probable that these seams were those in which machine coal-cutters should be tried, and where its economy ought to be greatest. The greater number of the seams ranged from 2 feet to 3 feet in thickness, and, though these generally work more freely, yet there should here again be a good opening for machine coal-cutters. A drawback to their adoption arose from the faulted nature of the district, which frequently either created several levels in a single district, or cut off the coal and necessitated it being re-opened anew. The great drawback in his opinion to the adoption of coal-cutting machinery in such thin seams was the large capital expenditure necessitated, owing to the generally small districts and their scattered nature, which would increase the capital expenditure and the cost of supervision. The roof, as a rule, does not require any unusual quantity of timber, the rows of timber being generally set from 2½ feet to 2¾ feet apart; and under a fresh roof and with quicker working this distance might be increased.

It was interesting to learn that the term "rice-wood" was not a local term only, as he had previously understood, but was in use in the Cleveland district of Yorkshire and the coal-fields of Germany.

The Chairman (Mr. H. C. Peake), in moving a vote of thanks to Mr. G. E. J. McMurtrie for his paper, said he had generally thought that most of the difficulties of mining were to be found in South Staffordshire, but he was glad to see that his life had not been thrown into this part of Britain. He had often pointed out that the under-cutting of a thick seam cost the same per yard as in the case of a thin seam.

Mr. M. Walton Brown seconded the resolution, which was cordially approved.

The following paper by Mr. W. A. E. Ussher on "The Culm-measure Types of Great Britain" was read as follows:—

THE CULM-MEASURE TYPES OF GREAT BRITAIN.

By W. A. E. USSHER.

Communicated by permission of the Director General of H.M. Geological Survey.

I.—Introduction.

Our greatness as a nation has been so largely built up on the industry prompted and fostered by the mineral wealth of these islands, and to that industrial development our coal-fields have so largely contributed, that the presence of the Carboniferous rocks suggests to us the occurrence of Coal-measures that have been denuded from the surface or may occur beneath it, or that may be troughed in by folds (similar to those to which we owe our coal-basins) under districts covered by more recent rocks, somewhere in the vicinity.

The economic importance of the formation in which is embedded the sunshine of a long bygone epoch, has stimulated geological research not only in the Coal-measures but in all strata which under the name Carboniferous, are included in the same general geological period. As a natural consequence the different types presented by the Carboniferous rocks in these islands have been carefully studied and described, and their various subdivisions have in most places been mapped out in detail. What has been done here in this respect has been done in nearly every civilized country of the world, where seams of coal have been obtained from rocks of Carboniferous age. Furthermore, attempts have been and are being constantly made to correlate the different lithological types presented by Carboniferous rocks of regions not only widely separated but in which during that period more or less dissimilar conditions prevailed.

In contributing a paper on the British Culm-measures, of which the writer has made a special but by no means exhaustive study, he feels to some extent called upon to justify the existence of that unproductive Carboniferous type so near the productive coal-fields of Somerset, Bristol and South Wales.

Literature.—On the literature of the Culm-measures of Devon, Cornwall and West Somerset, the writer need not dwell for long. Prof. Sedgwick and Sir R. I. Murchison, finding in Central Devon a group of dark shales, sandstones and grit, which contained here and there traces of plants locally carbonized, and was as a whole easily distinguishable from the rocks which bounded it on the north and south, christened it the Carbonaceous series. In 1837, the Rev. D. Williams, and in 1838, Mr. Weaver, divided the series into two groups:—(1) Culmiferous shales and sandstones, and (2) Wavellite-schistus and limestones. In 1839, the publication of the Geological Ordnance Survey Maps of Sir H. De la Beche, showed the general extension of the whole series and his report explained the structures illustrated by his sections. In 1841, Prof. J. Phillips gave a classification, in which he substituted "gritstone group" for the upper series of Mr. Williams and Mr. Weaver, and divided their lower group (the Wavellite-schistus and limestones) into three groups. During the survey of the New Red Sandstones of Somerset and Devon, between the years 1871 and 1880, the writer had many opportunities of studying the Culm in the northern, southern and central parts of the area, and again in 1887: the results appearing in a paper on "The British Culm-measures."* Since that paper was written, he has had the opportunity of amplifying his observations and mapping horizons in detail. But subsequent work has tended to the amplification rather than to correction of that paper, to which the reader is referred for many details which will not be given here.

II.—Classification of the Culm-measures and General Characteristics.

This classification will be found to differ in one respect from that of 1892, namely, as regards the affinities of the Exeter type. In other respects it is an amplification of it and so far as the present writer has been able to study the rocks in detail it is the natural grouping best adapted for tracing out structure. For example, the discovery of *Goniatites* in Culm-grits at Pinhoe and in rocks of the Exeter type between St. David's and St. Thomas' stations, Exeter, points to the inclusion of rocks of Middle Culm

* *Proceedings of the Somerset Archæological and Natural History Society*, 1892, vol. xxxviii.

types (locally at least) in the uppermost part of the Lower Culm, indicative of passage-beds; but on the ground a line could not be drawn to include them, and would be structurally misleading.

Upper Culm-measures.	Eggesford Grits.	Hard, rather thick, evenly-bedded grey grits, with shales and slaty beds.
Middle Culm-measures.	Tiverton and Morchard Types and Ugbrooke Types	Thickly and thinly bedded, greenish-grey and reddish, much jointed sandstones, associated with ovoidally splitting shales.
		Rather thick, grey shales with hard, fine, coarse, and locally conglomeratic sandstones, irregular in association.
	Exeter Type.	Interbedded, hard, thin, brown, weathered grits and splintery or broken grey shales (probably a local type).
Lower Culm-measures.	Limestone Series.	Dark shale or mudstone, *Goniatites* occasional, persistence not proved.
		Hard and soft shales with very hard mudstones, sometimes cherty, limestones occasional in some districts, well developed in others. *Posidonomya Becheri* and *Goniatites*.
	Coddon Hill Beds.	Hard cherty shales, with chert-beds locally developed. Radiolaria.
		Hard dark mudstones.
	Basement Beds.	Dark shales and slaty shale.

The Lower Culm-measures are marked off from the Middle and Upper types by the absence of grits, by the fine nature of the sediment, and by the hard, even, siliceous beds and limestones which they contain.

The rocks of the Exeter type are distinguishable by the thin even bedding of the grits and by the splintery or broken character of the shales. Those of the Morchard and Ugbrooke Park types by variation in grain, thicker bedding, irregularity of association with shales and slaty mudstones, felspathic ingredients more or less prominent, and a very local finely conglomeratic character. The Tiverton type is more jointed, even and regular in bedding, and the associated shales are distinguishable.

The Upper Culm-measures or Eggesford Grits are distinguishable from the Middle by their texture, evenly bedded character, absence of irregular or close jointing. These distinctions are of course general, especially as applied to the types of Middle Culm-measures.

The Lower Culm-measures are, geologically speaking, the most important division. The sub-division of it is based on the districts in north Devon and west Somerset, and in south Devon, which display the sequence best, but it may have to be modified locally when the results of detailed map-

ping have accumulated sufficiently to permit of the numerous isolated and faulted tracts being pieced together. The most valuable palæontological horizons are included in the upper beds, in which *Posidonomya Becheri* and *Goniatites spiralis* are characteristic and locally plentiful, and in which the limestones of Ven, Bampton, Westleigh, etc., occur. Radiolaria may or may not prove to be confined to a definite stratigraphical horizon: their discovery by Mr. Howard Fox is a most interesting and important one, and in the numerous papers* which he has written in conjunction with Dr. Hinde, describing the localities throughout the Lower Culm districts, in which he has found them "both in the very hard and cherty and in the soft shaly beds," there are valuable landmarks for the presence of Lower Culm rocks. Nevertheless, until the whole area has been mapped out in detail, a very troublesome, long and laborious process, it is not possible to say whether the classification which the writer has given of the Lower Culm succession is of general application beyond the districts in the north and south, where it is certainly proved true by detailed mapping. Cherty beds are common to different horizons; they occur in the calcareous horizons, and are prevalent below them; but as apparent superpositions may be inversions, outside the districts where he had separated out the Lower Culm-measures he could not speak with any authority as to the relative positions of the calcareous and chert horizons. In districts where he knew of their occurrence only by observations of sections or traverse work, he could say nothing, as any generalizations applied to contorted areas, broken and displaced by faults, cannot be regarded as conclusive, and where there is a possibility of the overlap of the Middle Culm-measures they are very liable to error. The base of the Coddon Hill Series is above the dark shale group, but he was inclined with diffidence to think that its upper limit may be locally sufficiently elastic to extend through the higher beds.

* (1) "On a Well-marked Horizon of Radiolarian Rocks in the Lower Culm-measures of Devon, Cornwall and West Somerset." By Messrs. G. J. Hinde and Howard Fox. *Quarterly Journal of the Geological Society*, 1895, vol. li., pages 609-668, plates XXIII.-XXVIII. (2) "The Radiolarian Cherts of Cornwall." By Mr. Howard Fox. *Transactions of the Royal Geological Society of Cornwall*, 1896, pages 21-31. (3) "Supplementary Notes on the Radiolarian Rocks in the Lower Culm-measures to the West of Dartmoor." By Messrs. G. J. Hinde and Howard Fox. *Transactions of the Devonshire Association*, 1896, vol. xxviii., pages 774-789. (4) "Additional Notes on the Radiolarian Rocks in the Lower Culm-measures to the East and North-east of Dartmoor." By Messrs. G. J. Hinde and Howard Fox. *Transactions of the Devonshire Association*, 1897, vol. xxix., pages 518-523.

All stratigraphical work is assisted by the discovery and placing of lithological horizons, for it is by the extension of such groups that the general structure is obtained. Consequently the Upper Culm-measures or Eggesford Grits are in this respect of considerable value, and any classification which accentuates the base by omitting the top is of course erroneous.

Before quitting this branch of the subject, the volcanic districts in the Culm-measures should be mentioned. These are confined to the southern part of the area and restricted to the Lower Culm-measures and the Upper Devonian slates which underlie them. The Tavistock area seems to have been the chief seat of vulcanicity, but there is reason to conclude that in more southerly districts, near Saltash, the volcanic rocks form the lower part of the same series. From Henn Point, on the Tamer, westward to St. Erney and between Lower Compton (on the north-east side of Plymouth) and the estuary of the Plym, hard grits occur in the vicinity of the volcanic rocks in places. Ashton and Trusham also experienced volcanic disturbances during the deposition of the Lower Culm-measures, but to a lesser extent. The volcanic rocks consist of brown weathered vesicular rock with fluxion-structure, schalsteins, tuffs and probably dolerites. Intrusive dolerites also occur in the Lower Culm-measures and in a few cases penetrate the lower beds of the Middle Culm-measures.

III.—Distribution (Plate XVI.).

The Culm-measures occupy an area of more than 1,200 square miles south of a line drawn from Wellington, in Somerset, westward by Kittisford, Morebath and Brushford to Barnstaple; and their southern boundary is very irregular and complicated by numerous faults. When studied in detail the differences between the northern and southern boundaries of the Culm and Devonian rocks are still further accentuated.

The northern boundary, although faulted in places and in parts sinuous through curves, marks off Culm rocks in which there are no inliers of Devonian, from Devonian rocks on which there are no outliers of Culm-measures.

The southern boundary, on the contrary marks off Devonian rocks with outliers of Culm-measures, indicating a considerable southerly extension of that formation, from Culm-measures in which inliers of Devonian occur locally. The southern main

boundary runs very irregularly from Whiteway Barton, south of Ideford, to Bickington; from thence to the vicinity of Ashburton, whence it bends southward along the eastern margin of the Dartmoor granite toward Ivybridge; resuming on the western margin of the granite near Tavistock, it sweeps round the granite of Bodmin Moors to Boscastle or Forrabury.

The granites of Kit Hill and Hingston Down suggest the existence of a subterranean granite-ridge connecting them with the granite of Bodmin Moors on the west and of Dartmoor on the east. South of this line, a considerable outlying tract of Culm-measures commences in outliers near Calstock and Beer Alston, and extends from the banks of the Tamer westward through St. Mellion, and Pillaton towards St. Cleer. This is by far the largest outlier hitherto discovered. Near Tamerton Foliot, at about 3½ miles north of Plymouth, two outliers have been found. South of Saltash, between Henn Point, Wearde Quay, and Forder Lake and, occasionally, between Forder Lake and St. Erney (3 miles south of Pillaton), sandstones occur, as also at Efford, between Lower Compton and Crabtree on the north-eastern side of Plymouth. They resemble Culm grits.

Altered rocks, which may be in part of Lower Culm age, occur on and near the western border of the Dartmoor granite near Peak Hill and Walkhampton, and on its south-eastern and southern border between Dean Church (south of Buckfastleigh) and Ivybridge, and probably also in the vicinity of Cornwood. Inliers of Devonian rocks occur in the Culm-measures between Bickington and Ilsington, and near Lydford. Between Kittisford on the north and the Teign estuary on the south, the easterly extension of the Culm-measures is concealed by the New Red Sandstone Series which also extends westward of its normal boundary for 5 and 20 miles respectively, in the Tiverton and Crediton valleys. From Stoodley Beacon eastward the Culm rocks on the north of the Tiverton valley are capped by several New Red Sandstone outliers. Outliers also occur at Hatherleigh, Essworthy and High Hampton, proving the former extension of the New Red Sandstone west of its termination in the Crediton valley. Inliers of Culm-measures occur in the New Red Sandstone at and north of Spraydown, and between Cullompton and Broadclyst.

Culm rocks form the coast-line from the mouth of the river

Taw to Boscastle. The Upper Culm-measures or Eggesford Grits occupy most of the coast-line from the small New Red outlier of Portledge Mouth to Hartland Point. To what distance they extend southward from Hartland Point toward Bude the writer is unable to say, as he has not visited that part of the coast. They are well exposed by the Torridge near Great Torrington and at Eggesford, and terminate eastward about halfway between Eggesford and Tiverton. Their termination seems to be in two bands, probably coalescing west of the Torridge valley.

The Middle Culm-measures form the larger part of the Culm area; the Tiverton and Crediton valleys have been eroded in them, and they extend westward from Exeter to Holsworthy and Bude. They constitute the major part of the outlying tracts between Beer Alston and St. Cleer, as well as the smaller outliers of St. Erney, Wearde Quay, near Saltash, and Efford, north-east of Plymouth.

The Lower Culm-measures extend on the northern margin of the Middle Culm-measures from Fremington through Tawstock over Coddon Hill through Swimbridge to Castle Hill. They are faulted out near South Molton and Molland, coming in again toward Brushford and extending through Bampton to Ashbrittle; their upper boundary curving to successively lower latitudes so as to embrace the limestones of Holcombe Rogus, Hockworthy, and Westleigh, near Burlescombe.

The distribution of the Lower Culm-measures on the southern margin is extremely irregular. They are present at Tintagel and Camelford, and extend from Boscastle by Launceston, Lifton and Bridestow: their upper boundary curving round the northern margin of the granite by Okehampton and Drewsteignton includes the hills on which Doddiscombsleigh, Ashton and Trusham are situated, and extends thence to Bovey Tracey. There are faulted patches of Lower Culm-measures near Chudleigh, Oldchard Well, and Bishopsteignton. From the Bovey valley, these beds extend round the granite to Ilsington and Holne, being denuded from its margin near Buckfastleigh; but they may be represented south of Wallaford Down, by a series of highly altered banded rocks at Brent, Wrangaton and Ivybridge. At Brent, the altered rocks contain scapolite.* Similar highly altered flinty rocks occur at

* Identified by Mr. J. J. H. Teall, F.R.S., P.G.S.

Camelford and on the western margin of Dartmoor. General MacMahon* has shown that in the neighbourhood of Sourton Down and Cocks Tor they are largely due to the alteration of volcanic rocks and greenstones associated with the Lower Culm-measures. This also is the case in the vicinity of Brent, and near Christow and Bridford, where the volcanic and intrusive rocks in the Ashton and Trusham Lower Culm-measures lie within the periphery of alteration bordering the granite.

The area covered by the Lower Culm-measures on the west of Dartmoor is much more extensive than that on the east, and the volcanic rocks of the Tavistock area indicate a longer period of vulcanicity than those of the Ashton and Trusham districts, which, although belonging to the same series, commenced later.

The Lower Culm-measures are well represented in parts of the outlying tract west of Beer Alston; but they are so faulted and disturbed that their entire absence in places, as at Calstock, near Beer Alston and Pentillie, etc., where the Middle Culm sandstones rest directly on Upper Devonian, may be due to faults and thrusts rather than overlap or unconformity. The Tamerton Foliot outliers belong to the Lower Culm-measures.

In the vicinity of the sandstones of Wearde Quay and St. Erney are occasional traces of rocks resembling Lower Culm-measures in association with volcanic rocks. It is not improbable that in this and the Plymouth district Lower Culm-measures were associated with volcanic rocks as at Tavistock, and that these were removed by denudation during an elevation of the sea-bed, which preceded the formation of the sandstones—the writer cannot prove the age of the latter.

Contemporaneous igneous rocks occur in the Upper Devonian in the immediate vicinity of the Wearde, St. Erney, and Efford sandstones, and these igneous rocks correspond to the lower part of the Devono-Carboniferous volcanic group. It has cost the writer several years to work out the evidence pointing to the above conclusions which bear out in a remarkable degree the opinions expressed by his old friend Mr. Rutley,† that the comparatively uniform character of the schistose volcanic rocks in the Tavistock, the Saltash, and the Cornish districts may be a con-

* *Quarterly Journal of the Geological Society*, 1894, vol. l., pages 338-366.

† *Geological Survey Memoir on Brent Tor*; and *Quarterly Journal of the Geological Society*, 1880, vol. xxxvi., pages 285-294.

sideration to some extent influencing "the position of the boundary-line between the Devonian and the Culm series on the west of Dartmoor." Mr. Rutley considered that while some of the emissions from the old vent on Brent Tor were limited, others " covered a very considerable area; and that some of the Saltash and Tavistock schistose lavas may possibly have represented a large and once continuous flow." Not having visited Saltash he gave the latter opinion guardedly. These questions he remarks " are neither to be solved by a few weeks of desultory stonebreaking, nor by a lifetime of speculation based upon imperfect data."

By detailed mapping in both districts the volcanic rocks have been proved to occur in the Upper Devonian and throughout the Lower Culm-measures, but not in the Middle Culm-measures. Hence the correlation advocated by Mr. Rutley is not in the least affected by the igneous rocks being associated with Culm-measures in one area and with Upper Devonian in the other. In the main he was structurally correct in his diagnosis, the relative and general contemporaneity of the rocks being scarcely affected by emanation from local vents, such as seemed to have existed in the vicinity of Henn Point, south of Saltash.

The occurrence of the Tavistock volcanic series among the altered rocks on the western flank of Dartmoor has been ably demonstrated by General MacMahon. At Meldon Viaduct, he has identified altered volcanic tuffs in association with the Lower Culm-measures; at Sourton Tors, altered tuffs and felsites with numerous fragments of ejected materials, trachytes, altered dolerites (porphyritic epidiorite); and on Cocks Tor epidiorites and altered rocks, once fine-grained beds of volcanic ash. The description of the latter accords with types of the Peak Hill rocks near Dousland and Walkhampton, and probably also with similar rocks on the borders of the granite north and west of Brent, and in the Ashton and Trusham district. Volcanic rocks are associated with the Lower Culm-measure between Hennock and Bovey Tracey.

IV.—Relations of the Middle and Lower Culm-measures.

The Middle Culm sandstones of Ugbrooke Park contain conglomeratic beds with fragments of chert, etc., which may have been derived from the Lower Culm-measures; and the discovery of granite-fragments in them by Mr. Somervail confirms the

writer's doubtful mention of decomposed felspar-fragments.* Conglomeratic beds or fine conglomerates also occur near Oldchard, at Rydonball and Twomiles Oak, south of Newton Abbot, and in other places. The Middle Culm sandstones in south-western Devon and eastern Cornwall generally, often include small dark shale-fragments, are felspathic, and vary in texture from fine to coarse-grained rocks.† The position of outliers directly on Upper Devonian, near Beer Alston, seems to point in these districts to an unconformity sufficiently great to have permitted of the complete or partial denudation of the Lower Culm rocks and of volcanic beds associated with them; and as the Lower Culm-measures are certainly indicative of deposition in much deeper water than the Middle Culm sandstones, which often display false bedding in these districts, it is probable that the upheaval of the sea-bed was so irregular in the volcanic districts that Middle Culm-measures elsewhere apparently conformable to the Lower Culm-measures (as regards position) were partly formed by the denudation of the Lower Culm-measures, and so rest on Upper Devonian rocks with volcanic intercalations belonging to the lower part of the Devono-Carboniferous volcanic series.

As regards the extension of limestones in the Lower Culm-measures where that division has been mapped out in detail, they have been proved to occur in the upper part of the series. At Venn, near Barnstaple, they are certainly overlain by the sandstones and shales of the Middle Culm-measures. At Westbrook and Duvale quarries, west of Bampton, they are overlain by dark shales which form the uppermost stratum of the Lower Culm-measures. Farther west, at Hele, south of Dulverton Hill (south of Dulverton station) the limestones have been decomposed, leaving a brown or yellowish-brown residue, in which *Posidonomya Becheri* is abundant, a similar phenomenon being observable on the east of the Bampton quarries. So far as the writer has been able to study the Culm limestones, they are very irregular in development, vary in character from dark earthy limestones (similar to those in the Launceston district) to more or less siliceous limestones as in the Bampton and some of the Westleigh limestone-hills, and in parts of the Ashton district; and exceptionally, as in the Whipcoats quarry, north of Westleigh, they have a dolo-

* "The British Culm-measures," page 141.

† The grits of Wearde Quay and Efford exhibit similar characters, but no plant-traces have been found in them.

mitic aspect and weather in irregular cavities. In most of the sections, they are contorted, and so interbedded with shales and hard cherty beds and mudstones, that it is impossible to ascertain their thickness. Even in the Westleigh patches, chert-beds or thin bands between the beds, and patches in them apparently resulting from segregation, are by no means uncommon. Messrs. Hinde and Fox state, "At the Canonsleigh quarries not far from Burlescombe station, there are cherty masses in the limestones and sections of these show faint outlines of radiolaria and sponge-spicules. Some of the limestones are foraminiferal, and contain a small form of *Endothyra*."*

This quotation is of peculiar interest, as proving that radiolaria are not confined to the Coddon Hill beds. The manner of occurrence of the limestones in the northern outcrop points to local developments, beyond which the beds of limestone finger out in the associated shales and mudstones. In the southern area, a similar mode of occurrence is exemplified, but the limestone developments are inferior in character and extent to those of Westleigh. The limestone of Woodah, near Doddiscombleigh, and the few individual beds met with elsewhere, occur in the upper part of the Lower Culm-measures, and above the chert-beds of the Coddon Hill series; although chert-bands occur here and there in the *Posidonomya* and *Goniatite*-shales of the upper beds.

In Wooladon (or Lifton) limestone-quarry, very thin (papery) shales overlie dark shales and limestones, the whole being overlain by cherty-beds in which Messrs. Hinde and Fox obtained radiolaria.† In this district, which the writer has never examined in detail, he was led during traverses made in 1888 to regard the above as a natural superposition, and the discovery of conglomerate apparently belonging to the Middle Culm-measures directly above chert-beds seemed to confirm it. If his inference was correct, the succession of the Lower Culm-measures in this district differs from that in the districts on the northern and southern outcrops mapped in detail. If incorrect, the junction would be an inversion, and the position of the Culm conglomerate would mark a distinct unconformity. Otherwise radiolaria occur in the Lower Culm-measures above and below limestones, and citing Canonteign, also in them. The dark shales at the base of the Lower Culm-measures

* *Quarterly Journal of the Geological Society*, 1895, vol. li., page 619.

† *Ibid.*, page 623.

seem to be persistent along the northern outcrop, unless cut out by faults. On the southern outcrop, they are apparently well represented in the districts west of Ashton and Trusham, but beyond these their extension has not been ascertained, and it is not impossible that they may thin out. Where they occur it is often so difficult to ascertain their junction with the Upper Devonian, that the writer believes he was mistaken in including dark shales, with strings and lenticles of crinoidal limestone, in the railway-cutting west of Morebath, in the Lower Culm-measures and certainly in considering that the limestone-horizons of the Culm-measures passed northward into the basement dark shales.*

V.—Structure.

So far as the writer can judge, where unfaulted along their northern and southern margins, the Lower Culm rocks invariably rest on Upper Devonian. The Devonian rocks which emerge from beneath them on the north, and those which underlie them on the south differ in character. The former are largely associated with grits, indicative of deposition in comparatively shallow water, contain no contemporaneous volcanic rocks, and but little limestone. In the latter, volcanic rocks are of common occurrence, there are large local masses of limestone, and arenaceous rocks are restricted to the lower beds (the Lower Devonian).

Through the observations of De la Beche, Phillips, Holl, and others, it has long been known that the Culm-measures occupy a trough or synclinal basin, the edges of which are formed of corresponding strata which overlie the Devonian rocks on the north and south. The general strike of the rocks is east and west, the many deviations from this being due to faults and curves in the northern part of the area, and to the presence of obstructive masses in the southern part of the area, which afforded greater resistance to the north and south contractile post-Carboniferous movements than the less consolidated materials surrounding them; as a consequence the southern area is much more broken and disturbed.

Throughout the Culm-measure area there is evidence of numerous small anticlinal and synclinal folds, the tendency of which is to keep the beds of the same series at the surface and to obscure the larger structural folds. In south Devon, especially

* "The British Culm-measures," pages 120 and 121.

in the volcanic districts, the plications are often most intense where the bedding-planes are nearly horizontal, through zig-zag structures in the limbs of the larger curves: this structure is often visible west of Dartmoor.

As will be seen from the observations on the distribution of the rocks, the axis of the main synclinal of the Culm-measures is defined by the occurrence of the Eggesford Grits or Upper Culm-measures, which, occupying part of the coast-line between Bude and Hartland Point, run eastward through Torrington and Eggesford, beyond which they disappear in the direction of Tiverton through the troughing-out of their folds. In consequence of this easterly throwing out or shallowing of the main axis, the Lower Culm-measures extended from Bampton to Burlescombe in a series of curves which include the limestone masses of Holcombe Rogus, Hockworthy and Westleigh.

In the southern part of the area, however, all this uniformity in general structure has been thrown out of order and we find the strikes deflecting round the granite of Dartmoor in a manner perfectly inconsistent with the upheaval of that mass subsequent to their production, but quite in accord with the obstruction which such a mass in a rigid condition would have offered to the forces in the act of producing them. Whether the granite is Archæan or post-Carboniferous is quite immaterial as regards this purely mechanical and stratigraphical problem. All that is postulated by it is that the granite existed in its present position as a rigid mass when the post-Carboniferous movements, which imparted their general east-and-west strike to the Palæozoic rocks of the south-western counties, came into play and that it offered such resistance to them as to account for the abnormal distribution and strikes of the Culm rocks; and the same argument is applicable to the Cornish granite-areas.

The St. Mellion Culm area, with its many faults and disturbances, occupies a syncline separated from the main Culm area on the north by an anticline of Upper Devonian rocks wrapping round the granite-ridge of Kit Hill and Hingston Down.

From Plymouth and Tor Point, northward to the Culm boundary, no rocks older than Upper Devonian have been detected. This great extension of Upper Devonian rocks, coupled with the southerly extension of the Culm-measures, in the area between the granites of Dartmoor and Bodmin Moors, is not due to any increase

in the thickness of the strata, but to repetition by constant small plications, and very shallow larger curves.

East of Dartmoor, in the discovery of *Goniatites* in the Culm-measures of Cocktree Moor by Mr. Vicary, at Exeter and Pinhoe, according to specimens in his collection, and at Baldoak near St. Mary Tedborn and in Perridge Tunnel by the writer, we seem to have indications of anticlines of larger curves repeating the topmost horizon of the basement-beds at different altitudes in the Middle Culm area. All these observations tend to show that the main structural curves, throughout, are exceedingly shallow, and that no great thickness can be assigned to any recognizable subdivision of the Culm-measures in virtue of great superficial extension. Whether the small folds and contortions were formed after the larger structural curves, or were produced when the beds were in a more or less plastic condition; and the large structural curves at a subsequent stage in the movements when the beds were in a more consolidated state; the writer does not profess to decide beyond indicating the probability of the latter alternative.

The north-and-south movements had not only ceased long before the deposition of the oldest Secondary rocks on the borders of the Palæozoic area; but so long an interval elapsed that the strata bent and folded by them were extensively denuded. Thus the earliest Secondary rocks are found to rest unconformably on Upper, Middle and Lower Devonian, and on Middle and Lower Culm-measures. Therefore, prior to their deposition, the whole of the Carboniferous Series and the greater part of the Devonian had been in places denuded from the anticlinals.

Owing to denudation, we have in the Eggesford Grits merely a provisional top to the Culm-measures. It affords a valuable structural landmark, but gives no clue as to its position relative to the productive Coal-measures, which in all probability once overlaid the Culm-beds.

Before proceeding to the next branch of the subject it may be well to sum up the preceding observations.

Summary.—The Culm type of Great Britain consists of a series of intercalated grits, shales and sandstones, with occasional plant-traces constituting the Upper and Middle Culm-measures, upon a series of fine sediments with marine fossils, with beds of lime-

stone and chert: the limestone is locally developed, also the cherts which contain radiolaria.

Volcanic rocks occur in the Lower Culm-measures in the areas between the Devon and Cornwall granites, and on the borders of the former.

Outliers of Middle Culm-measures on Upper Devonian rocks, near Beer Alston (possibly also near Saltash and Plymouth), justify the belief that the Lower Culm-measures had been locally denuded, prior to or during their deposition, while in neighbouring districts such a denudation (if any) was very slight.

The Culm rocks are repeated by numerous folds tending to obscure the main structures, which are very shallow. The Lower Culm rocks correspond on the northern and southern lips of the main synclinal, and rest exclusively on Upper Devonian strata. But while the northern lip is comparatively regular, the southern has been wrenched out of its true position, which should probably be along a line connecting Boscastle and the Teign estuary. The movements which produced the east-and-west strikes were much obstructed in the granite areas, and in consequence the strata are much faulted and disturbed. Outliers of Culm rocks occur in parts of the southern Devonian area.

VI.—Foreign Equivalents and General Correlation.*

The Culm type is by no means confined to Great Britain. It is found in Westphalia, in Nassau, in the Upper Harz, Eastern Thuringia, Saxony, Silesia and Moravia. The writer is not personally acquainted with any of these areas, but from the perusal of works by observers who have attentively studied them one cannot fail to be struck with the general similarity of the rocks, and the accentuation in some areas of phenomena, which are rare or local in the British types, such as the development of conglomerates, the thickening of the limestone-horizons, and the absence or partial representation of the Lower Culm-measures through unconformity. An epitome of the relations of the Culm rocks in the areas above mentioned is given in the writer's paper on "The British Culm-measures."†

* Fig. 4, Plate XVII.

† *Proceedings of the Somerset Archæological and Natural History Society*, 1892, vol. xxxviii., pages 169 to 180. A regrettable error of transcription on page 177 has been overlooked till now: Mr. Dalmer considers the Wildenfels Culm as older than the Chemnitz Hainischen, and not newer.

In Westphalia, the Flötzleerer sandstones are equivalent to our Middle and Upper Culm-measures, above them are the Coal-measures of the valley of the Ruhr, and below them Prof. Kayser describes the top of the Lower Culm-measures as a persistent band of alum-shale below which the beds "exhibit small differences in nearly every section, which are specially influenced by the very different thickness and purity of the Kieselschiefer (chert-beds) and limestone." The Carboniferous Limestone commencing at the base of the Culm-measures in a bed 1 foot thick at Nevigues increases to over 100 feet near Düsseldorf, and the Lower Culm-measures diminishing in the same proportion are not represented at Aix. Saving in the persistence of an upper shale-band, which cannot be proved, this description agrees very well with the behaviour of our Lower Culm-measures outside the volcanic areas. As regards the relations of the series to the Carboniferous Limestone, when we consider the distance intervening between the Carboniferous Limestone of Cannington Park and the Mendip Hills and the nearest exposures of the Culm type between Kittisford and Burlescombe, it seems highly probable that a similar reciprocity has led to the northerly replacement of our Lower Culm types by Lower Limestone Shales and Carboniferous Limestone: the easterly thickening of the purer Culm limestones between Bampton and Westleigh tends, moreover, to confirm this view.

As regards fossils, Messrs. Hinde and Fox have given two very valuable tabular lists in which the fossils from the Coddon Hill Beds in which they obtained radiolaria are kept separate from those of the calcareous horizons. They state that "of the 29 species recorded from the (Lower) Culm of Aprath by Prof. Kayser, 11 are found in our Culm Series and 9 of these in the radiolarian beds. Of 44 species from Herborn in Nassau, described by Dr. von Kœnen, there are only 7 identical with the English beds."*

"The macroscopic fossils which occur in the radiolarian (Coddon Hill) beds are either identical with, or closely allied to, species found in the Carboniferous Limestone of Yorkshire, Scotland, Ireland and Belgium, many of them are present in the Lower Culm-beds of Germany, and they indicate that these radiolarian beds represent the Carboniferous Limestones of other portions of the British Isles."† "The relationship of the Waddon Barton beds

* *Quarterly Journal of the Geological Society*, 1895, vol. li., page 659.

† *Ibid.*, page 660.

with *Trilobites* and *Goniatites spiralis* and the dark *Posidonomya*-shales and limestones of Devon, etc., to the Lower Carboniferous of Westphalia and the Harz was pointed out some years since by Dr. Henry Woodward. That of the radiolarian beds of Coddon Hill to the Kieselschiefer is of a still closer character."* If in the above passages, the authors do not include the Culm Limestones in the representation of the Carboniferous Limestone, the writer cannot agree with them. They give 23 genera of radiolaria of which "21 have been previously determined from the Palæozoic formations of this country and the Continent, the larger proportion —17 genera—from the Culm of Germany, Sicily and Russia by Dr. Rüst. Of the other 2 genera, one (*Trigonocyclia*) has not previously been recognised below the Jurassic, and the other (*Stethodiscus*) although a very simple form, does not seem to have been hitherto met with in the fossil state."†

Some of the fossils described by Messrs. Hinde and Fox are from the collection of Mr. J. G. Hamling, than whom no one has a more intimate knowledge of the Lower Culm-measures in the neighbourhood of Barnstaple. All that the writer has to say about that area is that the limestones of Venn underlie the shales and sandstones of the Middle Culm-measure, and they overlie the Coddon Hill Beds; but what are their actual relations to the beds of Coddon Hill, the writer has not had the opportunity of ascertaining.

In the Upper Harz, Mr. Groddeck‡ mentions the occurrence of shales containing *Posidonomya Becheri* and *Goniatites crenistria* with intercalated thin beds of grauwacke at the top of the Lower Culm-measures. This suggests a comparison with the Goniatite occurrences at Bonhay Road, Exeter, at Pinhoe, and in Perridge Tunnel. Messrs. Hinde and Fox state that "in the Upper Harz, near Clausthal, Lautenthal and Lerbach, in beds of adinole, wetzschiefer and kieselschiefer or lydite, Dr. Rüst has described a large number of radiolaria."§

Mr. H. M. Cadell, cited by Messrs. Hinde and Fox, gives the descending sequence of the Culm-measures of the Upper Harz

* *Quarterly Journal of the Geological Society*, 1895, vol. li., page 660.

† *Ibid.*, page 643.

‡ *Jahrbuch der Geologischen Landesanstalt und Berg-Akademie*, 1882.

§ *Quarterly Journal of the Geological Society*, 1895, vol. li., page 659

with thicknesses, as:—*Posidonomya*-schiefer and Culm limestone, 425 feet; and adinole, wetzschiefer, grauwacke and some lenticular limestones, 100 feet, resting conformably on Upper Devonian.*

From Mr. Liebe's account, the true Lower Culm-measures in Eastern Thuringia seem to be only represented locally and to consist of blackish oolitic limestones containing foraminifera, and in the extreme north-east part of the district one or two beds of dark grey limestone with brachiopods, altogether not more than 7 feet in thickness. Cherty geodes containing Goniatites occur above the limestones near Elsterberg.

The Lower Culm-measures probably pass up into the overlying shales and sandstones in places, through beds of calcareous grauwacke with crinoid-joints. Where the limestones are absent, a conglomerate of well-rolled fragments of granite and granitoid rocks forms the base of the Culm-measures. The Lower Culm-measures, according to Mr. Liebe, consist chiefly of shales furnishing roofing-slates with very thin grauwacke sandstones and only a few beds of coarse grauwacke. Conglomerates occur in it here and there, consisting of wellworn fragments chiefly of quartzite, quartz and shale, besides chert, adinole, orthoclase, plagioclase and carbonaceous alum shale cemented by a very fine sandy paste.† This description suggests a comparison with the Exeter type, and its replacement by the Ugbrooke Park beds, and the conglomerate of Oldchard in that neighbourhood, and of Rydonball south of Newton Abbot and other places. The roofing-slates of Tresmarrow near Launceston, for all the writer can say to the contrary, may also belong to the lower part of the Middle Culm-measures. The occurrence of nodules with Goniatites recalls a similar association at Instow.

Mr. Liebe's Upper Culm-measures consist of grauwacke of medium and coarse grain with intercalations of shale and contain conglomerate. Near Saalfeld and Elbersfeld there are some patches of diabase in the Lower Culm-measures but volcanic breccia ceased in the uppermost part of the Upper Devonian.

The feeble representation of the Lower Culm-measures in this area, and the character and position of the lower conglomerates

* *Proceedings of the Royal Physical Society of Edinburgh*, 1884, vol. viii., page 216.

† *Abhandlungen zur Geologie von Special Karte von Preussen und Thuringischen Staaten*, 1884, vol. v., part 4, page 24, etc.

suggest the idea of local unconformities and the denudation of Lower Culm-measures, chert-beds, etc., possibly associated with volcanic materials.

Separated from the above by the older rocks of the Frankenwald, and 11 miles south-south-west of it, another Culm-basin is described (by Dr. Richter) in which the Culm conglomerates contain many chert-fragments said to be derived from the Lower Silurian.* In this basin, the Culm-measures are shown resting directly on the Middle Devonian, and in its vicinity is an outlier of Upper Devonian. This seems to corroborate the idea suggested by the rocks in the other Thuringian basin, and, unless it can be accounted for by faults, indicates a very much greater unconformity than the writer has suggested in accounting for the position of the Middle Culm sandstones of Beer Alston, etc.

In Saxony, Culm-measures occur near Wildenfels, south-east of Zwickau, in an area of 3 to 4 square miles in which Upper, Middle and Lower Devonian as well as Upper and Lower Silurian rocks are also represented. Another Culm-area is found near Chemnitz and Hainischen, between Zwickau and Dresden. According to Mr. Dalmer, the Wildenfels Culm-measures consist of earthy shales with numerous sandy bands and streaks, and of grauwacke conglomerate and limestone.† The conglomerates are characterized by an abundance of chert-fragments as well as of quartz, felspar, shale, quartzite and diabase, but the Archæan detritus of which the Chemnitz-Hainischen Culm-measures are largely composed, does not enter into the composition of those of Wildenfels.

The limestones appear to be in part interbedded with the clastic rocks, and to occur also at the base of the series. They are thickly-bedded or massive, dark grey to black, and are very crinoidal. About ten beds are known, some only from 3 to 6 feet, others over 70 feet thick. They contain foraminifera and corals of Carboniferous Limestone species. In hand-specimens, the rock is not distinguishable from the limestones of the Fichtelgebirge. The Wildenfels Culm-measures rest on the *Clymenia*-limestones of the Upper Devonian, whilst the Chemnitz-Hainischen measures

* *Zeitschrift der Deutschen Geologischen Gesellschaft*, 1867, vol. xxi., pages 408-411, plate vi., prof. 3.

† *Ibid.*, 1884, vol. xxxvi., page 379.

rest nearly horizontally upon highly inclined Silurian phyllite and mica-schists, respectively. Mr. Dalmer concludes that the Wildenfels Culm-measures are not only older than those of Chemnitz-Hainischen, but that the major part of the elevation and folding of the Erzgebirge had been accomplished before the deposition of the latter, which was preceded by very considerable denudation, whilst the Wildenfels Culm-measures indicate only a small amount of erosion. Here again we have examples of the very different amount of denudation which preceded the deposition of the Middle Culm-measures in comparatively contiguous districts.

In Lower Silesia, near Hausdorf and Frankenberg, Mr. Dathe describes a small Culm-area consisting of sandy shales, finely fissile in the lower part, in thicker laminæ above, with numerous beds of sandstone often containing felspar-grains and forming arkoses. They are partly bounded by gneiss, and at their junction with it locally form gneiss-conglomerate. Numerous beds of gabbro-conglomerate occur at various horizons, some being at the base of the Upper Carboniferous Series, in which position at Reichels Koppe there are dolomitic limestones above them. Fossiliferous limestones are said to occur in the Lower Culm-measures in thin beds and lenticles, alternating with the shales and sandstones.* The fauna of the Silesian Carboniferous Limestone has been described by Mr. Semenow.†

According to Dr. F. Römer, the Culm-measures of Upper Silesia and Moravia, as typically developed in the districts of Troppau, Jagerndorf and Leobschütz, consist of an alternation of shales containing *Posidonomya Becheri* and not calcareous, grauwacke-sandstones and grauwacke-conglomerates containing the distinctive land-plants of the Culm-measures.‡

In Lower Silesia, Mr. Dames points out the occurrence at Freiberg of Upper Devonian limestone of the Harz type, as an inlier in the Culm shales and grauwacke.

* *Jahrbuch der Geologischen Landesanstalt und Berg-Akademie*, 1882 pages 228-260.

† *Zeitschrift der Deutschen Geologischen Gesellschaft*, vol. vi., pages 317-414.

‡ *Geology of Upper Silesia*, 1870. pages 56 and 57.

It is scarcely possible to base much on the descriptions of the Silesian and Moravian Culm-areas, but there can be no doubt as to the occurrence of calcareous and non-calcareous representatives of the Lower Culm-measures in them, and there seems to prevail throughout the series more or less evidence of marginal and shallow-water conditions, so that it would be idle to attempt any comparison between them and the British Culm types.

All the Culm-measure types to which we have referred occur between 49 and 52 degrees of north latitude. The westernmost, the British, lies on and to the south of the parallel of 51 degrees. The easternmost, the Upper Silesian and Moravian, lie between the parallels of 49 and 51 degrees, including the Lower Silesian areas of Freiberg and Hausdorf, which are much farther north than the more extensive Upper Silesian and Moravian areas. The Thuringian and Saxon basins lie south of the parallel of 51 degrees. The Harz Culm-area is the most northerly, occurring just south of the parallel of 52 degrees. The Westphalian area, including that of Nassau, which runs northward from the Taunus near Wetzlar to its eastern extremity near Arolsen, lies roughly speaking between 50½ and 51½ degrees. The productive Coal-measures occur in the western part of the Westphalian basin, between Dortmund, Essen and Elberfeld. The late Sir Joseph Prestwich, as quoted by Mr. McMurtrie,* gave the thickness of the Westphalian Coal-measures as 7,218 feet, the thickness of coal embraced in 117 seams being 294 feet, as compared with the thicknesses of 11,000 and 8,400 feet of the South Wales and Somerset Coal-measures respectively. There being 120 feet of coal in 75 seams in South Wales and 98 in 55 seams in Somerset, these discrepancies Mr. McMurtrie explained as due to the representation of the Pennant Rock by productive Coal-measures in the Continental coal-fields.

The Upper Silesian Culm-measures are overlain on the east by productive Coal-measures. We cannot therefore with justice regard the Culm types of Great Britain, any more than those of the Continent, as unproductive representatives of the Coal-measures, or consider their presence as detrimental to attempts made to prove the existence of Coal-measures under areas covered by newer rocks which probably conceal Culm types. Mr.

* (1) *On a Comparison of the Somerset Coal-field with the Coal-measures of Belgium, etc.* By Mr. James McMurtrie, Bath, 1890. (2) *The Geographical Position of the Carboniferous Formation of Somersetshire, etc.* By Mr. J. McMurtrie, Bath, 1873.

McMurtrie's papers should be carefully read in connexion with this subject, as no one is so well acquainted as he is with the area of the Somerset coal-field.

The second edition of Prof. Von Dechen's *Geological Map of Germany* gives the following tablets for the Carboniferous rocks in descending order, namely, (1) Productive Coal-measures, (2) Flötzleerer or barren beds, and Culm and Carboniferous Limestone. This is the simplest classification for general purposes and homotaxial with:—(1) Coal-measures, (2) Millstone Grit, (3) Carboniferous Limestone, and Lower Limestone Shales, where present. But in each area, the grouping of the rocks must depend on lithological distinctions which have stratigraphical value, whether they have any significance outside the areas to which they apply or not.

As regards the relations of the Lower Culm-measures to the Devonian rocks, the writer has not found any proofs of unconformity in the British area, so far as his detailed investigations have proceeded. In the Continental areas, taking for example the Thuringian basins in Eastern Thuringia, Mr. Liebe showed that the Culm-measures and Upper Devonian rocks overlap the Middle Devonian, the former resting directly on the Cambrian between Greiz and Pausa, near Lobenstein, with breccia representing the uppermost part of the Devonian intervening, between Greiz and Reichenbach. Hence he infers an elevation in the Middle Devonian period and a depression at the beginning of the Upper Devonian period, continued during the deposition of the older beds of the Culm-measures.

In the Southern Thuringian basin, where the rocks are apparently of Middle Culm-measure age, the fact of their resting on Middle Devonian on which an outlier of Upper Devonian occurs, and the abundance of chert-fragments in the Culm-conglomerates seem to accord very well with Mr. Liebe's explanation, supplemented by the elevation of the area after the deposition of the Lower Culm-measures, and their removal by denudation preceding and accompanying the shallow-water accumulations of the Middle Culm-measures.

Whether as a whole the Lower Culm-measures, where typically developed, represent deeper-water conditions than the Carboniferous Limestone or not, the writer does not profess to judge; but having regard to the great discrepancy in thickness that they

indicate, a much slower rate of accumulation seems more than probable, and this slower rate accords with the idea of deposition in deeper water advocated by Messrs. Hinde and Fox.* Nor does the manner of reciprocal replacement on the west of the Westphalian region described by Prof. Kayser conflict with this view: it enlarges the possibilities of Carboniferous oceanography, as the replacement of the Carboniferous Limestone by the Culm type would be a bathymetrical line on the one side, whilst the prevalence of the Northumbrian and Calciferous Sandstone Lower Carboniferous types would indicate the shallower areas of deposit on the other.

In a paper on "Coal-prospects South of the Mendips,"† the writer expressed the belief that the inliers between the Carboniferous Limestone of Cannington Park and the Quantocks were Middle Devonian and perhaps in part Lower Devonian, and pointed out the anticlinal structure of the Quantocks. A great deal hangs on the careful study of these inliers, as one cannot say where the Old Red Sandstone type of the Mendips ends on the south, and there is a possibility of the outliers representing it; or, in view of the anticlinal structure of the Quantocks, they may in part represent the Upper Devonian, in part the Middle Devonian, but in no case the Lower Devonian, as suggested in 1891.

The late Mr. T. M. Hall‡ regarded the Culm shales and grits as "of an age immediately antecedent to that of the true Coal-measures," and always referred to them as Millstone Grit and to the Culm Limestones as Carboniferous or Mountain Limestone.

VII.—Economic Geology of the Culm Series.

The Culm takes its name from the local occurrence in the Middle Culm-measures of beds and seams of anthracite. These are confined to the northern outcrop, not having been found, so far as the writer is aware, in the corresponding strata of the southern area. The late Mr. Townshend M. Hall described them in 1877§ as follows:—"In the Carboniferous Series, a line of inter-

* *Quarterly Journal of the Geological Society*, 1895, vol. li., page 661.

† *Proceedings of the Somerset Archæological and Natural History Society*, 1891, vol. xxxvi.

‡ *The Geology and Mineralogy of North Devon.* By Mr. T. M. Hall, Ilfracombe, 1877.

§ (1) "Remarks on the Distribution of Minerals in North Devon," *Mineralogical Magazine*, 1877, vol. i., page 212. (2) *The Geology and Mineralogy of North Devon*, Ilfracombe, 1877.

mittent beds of anthracite runs from Barnstaple Bay to Umberleigh station, a distance of 13 miles. These beds vary in thickness from 6 inches to 14 feet." And in another place, "Several beds of anthracite or culm, as it is locally called, may be traced from Greenacliffe, near Bideford, to Hawkridge Wood, near Umberleigh Station, a distance of 13 miles. At Hiscott, in the parish of Tawstock, which is about the middle of the bed, there are two veins 9 feet in thickness. They were first worked about the latter half of last century, and although the anthracite was of excellent quality, and the produce amounted to upwards of 900 bushels per week, the mines were discontinued about the year 1800 on account of the difficulty of keeping out the water. Under the town of Bideford, the beds vary in thickness from 6 inches to 14 feet, and were formerly worked with considerable success. Besides being used for fuel, the softer varieties of anthracite are ground to a powder for the purpose of a pigment, which is largely employed in the dockyards under the name of 'Bideford black.' The old series of the Geological Survey Map shows the position of the anthracite-beds." Although now worked, there is nothing to add to the above description. Mr. T. M. Hall added, "The fossils of the Millstone Grit consist almost exclusively of the remains of *Calamites*, *Sigillaria*, and other wellknown Coal-measure plants. The anthracite-beds present a more varied flora, and ferns are not uncommon. The total number of species obtained up to the present time [1877] amounts to 27."

As regards mineral wealth, the Culm-measures compare very disadvantageously with the Devonian rocks: the lower beds are in this respect the richest. Manganese has been worked in them near Doddiscombleigh, in and just below the chert-beds. Near Newton St. Cyres, apparently in the shales and grits of the Exeter type, an east-and-west line on the old series of the Geological Survey Map denotes the occurrence of manganese. The writer does not think that the manganese-deposits are true lodes, as the mineral is of common occurrence in the earthy decomposition-products locally associated with the chert-beds and in the residue after the decomposition of limestones. A very good example of this is furnished by a dark-brown decomposition-product after a thick bed of limestone in the Bampton quarries, which are now being worked.

Mr. J. G. Hamling tells the writer that the dark shales asso-

ciated with the limestone near Swimbridge, and in some other localities, burn slowly and their appearance is suggestive of a bituminous character. In all the limestone-developments, the strata have afforded materials for lime; but in this respect they vary: in the Bampton quarries for instance, some of the limestone-beds are worked for this purpose, and others rejected as worthless. The dolomitic-looking brownish limestone of Whipcoats quarry is not in much request, although the writer is told that it burns to a greasy lime, very suitable for agricultural purposes. Some of the Culm grits afford good building-stone, the sandstones of the Tiverton type of Middle Culm-measures, when well selected, being very useful in this respect, as they possess the workable properties of a freestone; but even in the thicker and less jointed beds, the stone, unless carefully selected and properly laid, is apt to flake off in weathering. Examples of this may be seen in St. Peter's Church, Tiverton; that handsome structure also displays, among the variety of material of which it is constructed, many stones from the Lower Culm limestone-horizons, in which hard mudstone or siliceous limestone are banded by dark chert, the same block often containing two or more chert-bands. An exactly similar association may be observed in the Bampton quarries. Mr. Badcock, of Bampton, in a pamphlet published for the visit of the Somerset Archæological Society to that town of July 26th, 1900, informed the members that the Culm limestones, judging from the age of Bampton Church, must have been worked for at least 600 years, "they furnish building-stone, road-metal and lime for agriculture, and masonry of most excellent quality. The building-stone is in flat level beds of all thicknesses from 1 inch to 3 feet, producing rectangular blocks ready for use as they leave the quarries." As a building-stone, as road-metal, and for lime, the stone is said to be unequalled. This may be given as a favourable sample of Culm limestones, without prejudice to those of the Westleigh area.

Like the Carboniferous Limestone, the Culm limestones, when not too impure and earthy, furnish better road-metal than the Devonian limestones. The Coddon Hill Beds are very serviceable as road-metal, the numerous even joints by which the beds are intersected often saving the trouble of further reduction in size, and where the chert-beds occur in tolerably thick beds, they are easily broken to the required size. The hard altered Peakhill

rocks too are broken up for road-metal—the intrusive dolerites and diabases in the Lower Culm-measures of the southern outcrops are also largely used for road-metal, and in some cases (as near Trusham station) can be dressed into small rectangular blocks, for building purposes.

Lead-veins are met with in the Culm-measures in the mineral districts, and have been worked; they are usually cross-courses running in north-and-south directions. As a general rule, however, the writer believes that when a mineral vein or lode passes out of the Devonian into the dark shales of the Culm-measures, it is said to lose its productive character.

The mineral which suggested the term "wavellite schistus" to Messrs. Williams and Weaver "was first discovered 'according to Mr. Hall' about the year 1785, in a band of indurated shale near South Molton." According to Messrs. Hinde and Fox, wavellite is "developed on the joint-planes of hard, dull, black, siliceous rock" in the westernmost of the quarries at the summit of Heddon High Down, about 2 miles from Swimbridge.*

At Tracebridge, the dark Lower Culm shales furnish hard, even, slate slabs. The writer cannot say whether the dark roofing-slates at Tresmarrow, near Launceston, are Lower or Middle Culm-measures.

VIII.—Summary and Conclusion.

The Culm-measures are a type of Carboniferous rocks, in England confined to Devon, western Somerset and eastern Cornwall, but found in Germany in many places between Düsseldorf on the east and Breslau and Krakau on the west, a distance of from 450 to 500 miles. Although in all these places, there are some points in common, the Westphalian and Nassau districts probably furnish on the whole the nearest analogues to the British types: in these districts moreover Coal-measures overlie the Flötzleerer sandstone which corresponds to our Upper and Middle Culm-measures.

The British Culm rocks consist of grits, shales and sandstones, constituting the Upper and Middle Culm-measures, and containing plant-remains; and of fine sediments, including limestone and chert-beds, constituting the Lower Culm-measures which contain a marine fauna with great numbers of radiolaria.

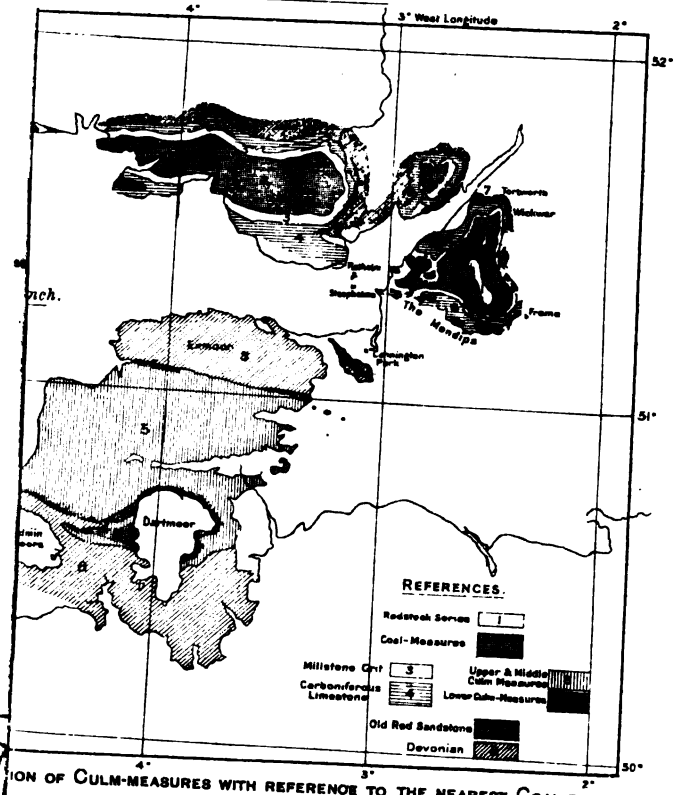
* *Quarterly Journal of the Geological Society*, 1895, vol. li., page 617.

The Culm rocks are repeated by numerous small plication the tendency of which is to keep the same series of strata at t surface; this is, however, counteracted by shallow curves undulations, which have the effect of troughing the Upper Culm measures along an axis (between Hartland Point and Bud running eastward and shallowing out towards Tiverton. T Lower Culm-measures correspond on either lip of the synclina resting in each case on Upper Devonian rocks; but whilst on t north they are comparatively regular, and contain no volcan horizons, on the south their distribution is exceedingly irregula Their deposition was locally accompanied and interrupted b volcanic eruptions, and their relation to the Middle Culm-measure in certain places justifies the belief that in or near the volcanic districts they were wholly or in part denuded prior to or during the deposition of the Middle Culm rocks, which form outlying fragments directly superimposed on the Upper Devonian.

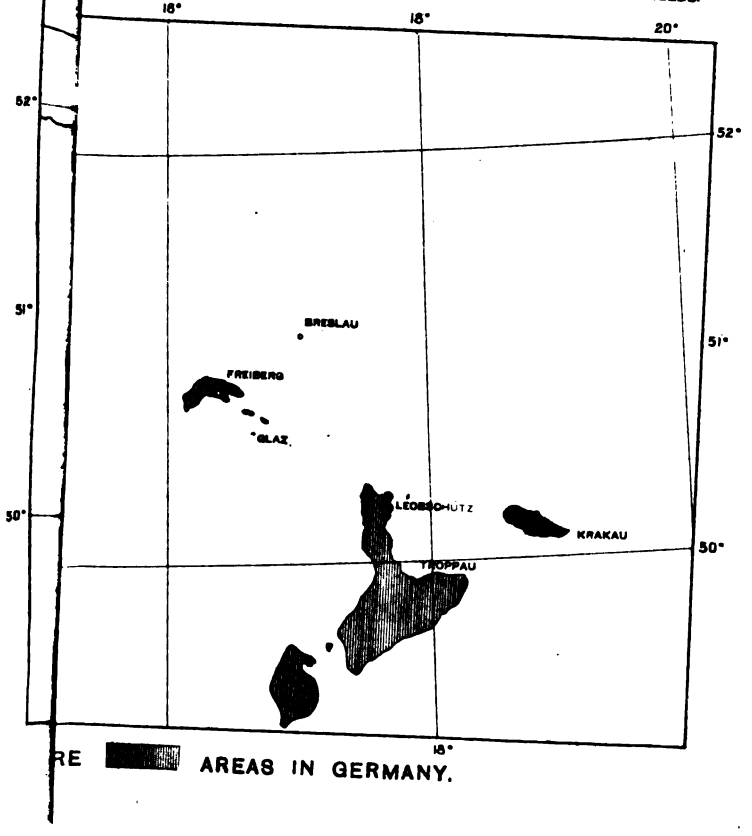
The irregular distribution of the Culm-measures, both Middle and Lower, in the southern districts seems to be due to obstruction to the north and south contractile movements by which the beds were plicated. These irregularities seem to have a direct relation to the granite-masses round which the strikes are deflected. The movements referred to had not only occurred before the deposition of the New Red Sandstone, but in the interval the Culm-measures had in places been completely denuded from the Devonian anticlinals.

The development of limestones in the Lower Culm-measures, at and near Westleigh, the point nearest to the Carboniferous Limestone of Cannington Park and the Mendips, is significant, and may indicate a north-easterly replacement of the Lower Culm-measures by Carboniferous Limestones.

The discoveries of radiolaria in the Lower Culm-measures, by Messrs. Hinde and Fox, favour the idea that these rocks were deposited in deeper water; and so their correlation with the Carboniferous Limestone is not impaired by the great discrepancy in thickness between them: whilst the Lower Culm-measures may not exceed 400 or 500 feet, to the Carboniferous Limestone of the Mendips is assigned a thickness of 3,000 feet. This correlation would justify the term Millstone Grit, by which the late Mr. Townshend M. Hall referred to the Culm-measure grits and shales, in the sense of the homotaxial relation of the Upper and Middle Culm-measures to the Millstone Grit.



ION OF CULM-MEASURES WITH REFERENCE TO THE NEAREST COAL-FIELDS.



RE AREAS IN GERMANY.

The little map (Fig. 3, Plate XVII.) showing the position of the Culm-measures with reference to the nearest coal-fields (adapted from an excellent map by Mr. J. McMurtrie) displays the change from east-and-west to north-and-south strikes which causes the Carboniferous rocks on the north of the Mendips to form a sort of neutral area in which the axes of the anticlines and synclines are not prolonged in a particular direction, but give rise to irregular domes and hollows. If this structure be maintained to the south and south-east of Frome, there is considerable probability in favour of the existence of coal-basins beneath the Secondary rocks of the south of England on either side of the parallel of 50 degrees of north latitude; but the best sites for trial-borings would be difficult, if not impossible, to define. Such basins would not be affected by the type of the Carboniferous rocks beneath the Coal-measures, whether of the Culm or Carboniferous Limestone type. If on the other hand, the broad shallow curves of the Culm area are prolonged beneath the Secondary rocks eastwards, the occurrence of coal-basins would depend on slightly deeper troughings which might or might not occur. The shattered and disturbed condition of the southern part of the Culm synclinal effectually forbids any reasonable guess as to its continuance or troughing out eastward beneath the Secondary rocks.

The little map (Fig. 2, Plate XVII.) showing the relative positions of the British and German Culm-measures indicates the irregular range of the type between the parallels of 49 and 52 degrees of north latitude. If the Westphalian was connected with the British region, the direction of the connecting deeps could only be proved by the discovery of the Lower Culm type beneath the intervening Secondary rocks.

In the map of the British Culm area (Fig. 1, Plate XVI.) volcanic rocks have been purposely omitted, as they could not be adequately shown on so small a scale, and are moreover undefined as yet over most of the area west of Dartmoor.

Mr. A. Strahan (London) wrote that Mr. Ussher's paper dealt with a region of great complexity, the sequence of strata given by the author having been established only by long investigation. It seemed strange at first sight that the closest counterpart to the Devon Culm-measures had to be sought on the Continent, and not

in the neighbouring coal-field of South Wales; yet that they have their representatives in that coal-field is certain. From the descriptions it would seem that neither the Pennant Series, nor the productive Coal-measures which lie below it, remain entire in Devon, whether or no they ever overspread that area. For the fossils of the Culm-measures appear to be marine, whereas marine forms occur in the lower part only of the South Wales productive Coal-measures, and there sparingly. The anthracitization, moreover, of the seams points to their having been deeply buried, and indicates that they are more probably of Lower Carboniferous than of Coal-measure age. The Millstone Grit, as well as the Carboniferous Limestone, is chiefly if not wholly of marine origin and these formations are doubtless correctly correlated with the Culm-measures by the author. There remains however the difficulty that the Culm-measures differ lithologically from both these formations, but the explanation that they represent deeper-water conditions receives support from the fact that there is evidence of land having existed not far north of the South Wales coal-field in Carboniferous times. The rocks all thin towards the north, and the limestone is even overlapped by the Coal-measures in Pembrokeshire, as happens in other parts of the kingdom in the neighbourhood of a shore-line. Southward, on the other hand, the strata not only expand, but change character rapidly from one side of the coal-field to the other. The determination of the age of the Culm-measures is of great economic importance in regard to possible concealed coal-fields in the south of England; for if they are of Lower Carboniferous age, they may be overlain in any such coal-field by productive Coal-measures of the normal type.

Mr. A. J. Jukes-Browne (Torquay) wrote that three points in Mr. Ussher's paper had struck him as being of special interest. (1) The first is the further advance made by the author toward a correct grouping of the Culm-measures of Devon. The determination of the real succession of the strata in Devon is by no means an easy matter, for even the Carboniferous succession cannot be read off like that of more northern counties, but owing to the manner in which the rocks are bent, plicated and faulted, it demands a great deal of careful and laborious stratigraphical work. Mr. Ussher's paper is the outcome of many years of such work, and is consequently the more valuable.

(2) The very decided local unconformity between the Lower and Middle Culm-measures, near Plymouth and Saltash, is an important stratigraphical fact. Mr. Ussher's suggestion that this unconformity is connected with the existence of contemporaneous volcanic rocks in the same district is also interesting, for it enables one to form something of a mental picture of the physical conditions under which the Lower and Middle Culm-measures were deposited. First, a deep and quiet sea in which a considerable thickness of mudstones and shales, with bands of limestone and chert, was formed; then the outbreak of volcanic action and the ejection of lavas and ashes, this volcanic action leading to a local upheaval, which brought certain parts of south Devon and north Cornwall above the surface of the sea, and caused the more or less complete destruction of the Lower Culm-measures within these areas. Thus, at the close of the Lower Culm-measure time, we may picture a sea dotted with a number of active volcanoes. It is interesting to remember that similar volcanic eruptions were in progress in Scotland at the same period of time. After this period of volcanic activity in Devon, the area again subsided, the volcanic islands were destroyed, and their materials went to form the conglomerates mentioned by Mr. Ussher as occurring in the Middle Culm-measures.

(3) The third point of special interest is the fact that the Carboniferous Series of Devon is incomplete, and that it is very probable that the Coal-measures were originally deposited on the top of the Culm-measures; further, although no remnant of such Coal-measures has yet been found in the exposed area, it is just possible that patches of them may come in below the secondary rocks on the eastern side of the Culm-measures syncline. This could only be decided by trial-borings, and many trial-borings would have to be made before it could be proved or disproved. The results of a couple of such borings made somewhere to the east or north-east of Cullompton could not fail to be interesting and instructive, but the person who bore the cost of them would have to be prepared for the failure to find coal.

Mr. J. G. Hamling (Barnstaple) wrote that he agreed with Mr. Ussher's conclusions respecting the geology of the Culm-measures in the neighbourhood of Barnstaple.

Mr. W. A. E. Ussher, replying to the discussion, wrote that

the selection of Continental types, rather than those of contiguous areas for comparison with the Culm-measures of Devon, etc., is due to the facts that:—(1) Culm rocks have been described in these areas; (2) they overlie as in Devon, etc., Devonian rocks; and (3) in two of the districts cited the Flötzleerer beds are overlain by productive Coal-measures. In South Wales on the other hand, he had no information as to the occurrence of rocks of the Culm types, and had had no opportunities for investigation. He looked forward to the progress of the work on which Mr. A. Strahan is engaged as likely to afford most valuable clues as to the nature of the transition from the Devon Lower Culm types to the Lower Carboniferous types of South Wales; and as to the correlation of the plant-bearing shales and grits of the Middle and Upper Culm-measures. He desires to thank Mr. Strahan for the useful information condensed in his remarks.

In Mr. Jukes-Browne's able word-picture of the local physical conditions likely to have prevailed during and subsequent to the deposition of the Lower Culm-measures, the outbursts of vulcanicity are taken as subsequent to the deposition of the Lower Culm whereas the author had endeavoured to show that these outbursts began during the deposition of the Upper Devonian and were continued at intervals into the Lower Culm, frequently obscuring the junction between the formations. It is of course possible that they may have continued throughout the deposition of the Lower Culm-beds in places where their absence is due to Carboniferous denudation, but there is no means of proving such to be the case.

The Chairman (Mr. H. C. Peake) moved a vote of thanks to Mr. W. A. E. Ussher for his valuable paper on the Culm-measures.

Mr. M. Walton Brown seconded the motion, which was cordially adopted.

The following paper by Mr. Edward Gledhill on "The Analogy between the Gold 'Cintas' of Colombia and the Auriferous Gravels of California" was read as follows:—

THE ANALOGY BETWEEN THE GOLD "CINTAS" OF COLOMBIA AND THE AURIFEROUS GRAVELS OF CALIFORNIA.

By EDWARD GLEDHILL.

Mr. Radford's excellent and practical paper* deals so largely with absolute fact that it offers but little scope for remark or discussion. The writer thinks, however, that by extending the subject of the paper to countries other than California, in which hydraulic mining had also, of late years, been established, a useful purpose might be served.

In this connexion there is one point not specially mentioned by Mr. Radford which the writer considers sufficiently important to lay some stress, especially as he sometimes finds it disregarded in estimating the results to be derived from a given calculated yield—he refers to the great loss of gold floated away during treatment, a loss which appears, under existing systems, to be inseparable from hydraulic mining where large volumes of water are employed. The importance of this loss is emphasized if it be remembered that the gold so lost would often make all the difference as between a profitless and a profitable result, or would at least, if properly taken into account, prevent many hopeless enterprises from being taken up. In the writer's opinion, founded on valuable opportunities for investigation, this loss in Colombia is scarcely ever less than 35 to 40 per cent., and more often than not exceeds 50 per cent., of the total gold-content of the gravel.

There is usually present not more than an average of some 2 to 3 grains in weight (say 0·000,002 per cent.) of tiny, flattened-out specks of gold, intermixed with every ton-weight of the 1,500 to 3,000 tons per diem of the clayey "gravel" that may be removed. This mass is impelled by a volume of water probably varying from 800 to 1,600 cubic feet per minute along a narrow

* *Trans. Inst. M.E.*, 1899, vol. xvii., page 452.

sluice at race-horse speed, and consequently a very considerable loss in gold could scarcely be expected to be prevented, but this loss may sometimes be reduced. Where the waste is unavoidable, and where the gross yield affords no margin upon the calculated estimates to cover such loss, the reporting engineers, whose calculations are based on such results, mislead others when they neglect to discount the inevitable loss of gold.

The most painstaking methods may be conscientiously employed, by means of trial-pits and trenches sunk and extended to ascertain the yield and continuity of the gravel; and by careful panning, or possibly by a " run " on a small scale under a limited and carefully adjusted supply of water the yield in gold per cubic yard of gravel may be ascertained, furnishing the data for future guidance. Nothing could be more misleading or disappointing, if no account be taken of the enormous loss subsequently arising when practical operations commence with the hydrant.

The writer, although more closely associated with vein-mining, had opportunities of arriving at an opinion on this point while directing the working of auriferous deposits in the Republic of Colombia, South America. There, the gravel-banks, in the department of Tolima, ranged in height from 25 to 150 feet, with a general average yield *in situ* of about 20 to 25 cents, or say 5 to 6 grains of fine gold per cubic yard. He found that with 250 miner's inches of water (say about 400 cubic feet per minute) passing through the hydrant (during the rainy seasons) under a head varying from 80 to 100 feet, a staff of from 8 to 10 men ran off gravel at the average rate of 25 cubic yards per hour, or almost exactly 1 cubic yard per miner's inch per day of 10 hours' running, and at a cost of about 6 cents per cubic yard. The result in gold averaged, during a considerable period, 11·4 cents per cubic yard (or at the rate of 11s. 10½d. per hour's running), showing an approximate loss in gold varying from 8½ to 13½ cents per cubic yard, notwithstanding great watchfulness during the operations.

During the dry season, precisely the same description of gravel was worked, without the hydrant, with 60 inches of water (say 96 cubic feet per minute) carried over the top of the bank simply as a running stream, which conveyed the dislodged gravel, as it was barred down by a staff of 16 native workmen, into the riffled sluice-boxes. Great care was taken, in both cases, to break up any lumps of clay, so as to prevent them from licking up and carrying away

the gold as they rolled along. By the latter system, 100 cubic yards of gravel were removed per day of 10 hours (or at the rate of 1·6 cubic yards per miner's inch of water) costing approximately a total of 12 cents per cubic yard, with a yield of gold averaging 20·6 cents per cubic yard, being a difference in value of gold saved of over 9 cents per cubic yard in favour of the process employing the smaller quantity of water.

It may be mentioned that the gravel referred to (which is more or less typical of the Tolima gravel generally) was readily disintegrated, almost free from pipe-clay, weighing about 1·8 tons per cubic yard, and deposited on a bed-rock of highly tilted micaceous schist and chlorite, probably Archæan. The lower or "blue" portion, highly charged with barren quartz-boulders, was, as is usually the case, the most productive, and more abundantly so in close contiguity to the bed-rock; although the "red" portion frequently yielded finely disseminated gold in lesser quantity. The gold was invariably associated with the fine "black sand" of the miners (magnetic iron) and occasionally with iridium,* but it was by no means uniformly distributed throughout the mass of the deposit. The best results were usually obtained from "channels," which from their conformation and direction as compared with the rise or fall of the bed-rock, and other local circumstances, had been favourable to the concentration and retention of the gold when the deposits were originally formed. These channels varied from a few feet to many feet in width, and were equally variable in regard to their length.

The richest channel of which the writer had experience was V-shaped, and not more than from 9 to 12 feet wide at the bottom; but after the customary fortnight's "run" the coarse gold lying on the bed-rock, and in the cuts and ground-sluices penetrating it, could, at the time of the clean-up, be scooped up by spoonfuls over the area of bed-rock from which the gravel had been removed. The deposit contiguous to this channel was, however, less rich than the average.

In confirmation of the writer's opinion that not only is gold, together with a portion of the quicksilver placed in the sluices, irretrievably lost by the employment of large volumes of water, and that the loss varies in the ratio of the quantity of water used

* In the Choco district of the Cauca, platinum is also found in association with the gold.

(other circumstances being the same), he may instance another hydraulic mine, in the same region, with an almost identical description of gravel and worked through a hydrant with 800 miner's inches of water—say 1,280 cubic feet per minute. The returns from this mine, assuming the yield to be approximately similar to the one above referred to, and if there were no loss of gold in proportion to the increased water-supply, should have amounted, at the rate of 11·4 cents per cubic yard, to £1 18s. per hour's running (the original estimates and reports were based on a far higher yield than this). As a matter of fact, the average return was only at the rate of £1 an hour, or say 6 cents in value of gold actually saved, the rest being evidently carried entirely out of the sluices by the volume and velocity of the current flowing through them. And, so far as the writer has been able to gather, the frequent, if not universal experience, at most hydraulic-mines is that the actual realizations fall immensely short of the calculated and anticipated returns.

It is not an easy matter to prevent a certain loss during hydraulic treatment, but in the writer's opinion the great loss in fine gold occurring in many mines might be considerably reduced by augmenting where possible, and by bestowing greater attention on the construction of under-current sluices, and by giving these an enlarged area with a diminished grade and multiplying their number, subdivide the flow passing through them, thereby affording the fine particles of float-gold more time to deposit and amalgamate with the quicksilver.

When pipe-clay is present, one must take the fullest precautions to prevent the rolling balls of clay from carrying away the gold by having them more thoroughly broken up during the passage down the sluice. And the writer would even recommend, where large volumes of water of, say, 1,000 miner's inches or over, are used, to employ this quantity, where it can conveniently be done, in two or more distinct sets of operations, using say 500 inches in each, rather than in one jet employing the entire volume. It is hardly necessary to say that in all cases the sluices should be kept at an uniform grade and in a perfectly straight line, all bends and deviations, by causing eddies and interruptions in the flow, preventing the retention of the gold, and the sluices should be as long as possible: certainly not less, and as much more than 1,000 feet as can be arranged for.'

Whatever may have been the original source of the gold, there appears to be a very close analogy between the auriferous gravels of California and those of Colombia. Both have deposits ranging from placers less than 20 feet thick to banks over 200 feet thick, the detritus being deposited on bed-rock of primitive sedimentary or granitic formations and having an approximately similar yield in gold. The gravels are similarly impregnated with rounded boulders of all sizes varying from mere pebbles to masses several tons in weight, the smaller sizes being often cemented into a compact conglomerate necessitating force to disintegrate them. The "blue" or unoxydized lower portions of the deposits overlain by those of an oxidized red or yellow colour are equally peculiar to both countries, and similarly contain ancient drift-wood in the form of carbonized fossilized branches and trunks of trees (partially converted into lignite) which, untold ages ago, were floated down by former rivers and buried in the accompanying detritus.

The writer has also occasionally met with, contiguous to Colombian deposits, the submerged silicified bones of the *Mastodon* and other extinct mammalia equally peculiar to some Californian deposits of the Pleistocene period, during which epoch the original gravels were apparently deposited.

What, however, is probably peculiar to Colombia are trinkets made from native gold, and stone chisels and other relics and implements frequently washed into the sluices, and formerly belonging to members of Indian tribes of unknown antiquity, with whom at the time of death they were possibly interred and remained buried during long ages until disturbed and unearthed by modern mining operations.

In both countries there are evidences of the originally deposited gold-gravels being broken up by subsequent floods, and redistributed and redeposited in other localities. In Colombia, the later deposits are usually shallower, and the gold contained in them exists in a more finely divided and flattened-out condition, as well as being more sparsely distributed.

To the three chief essentials for successful hydraulic gold-mining, namely: abundant and favourably located pay-gravel, water, and a suitable outlet, may be added a fourth condition, the necessity of ensuring freedom from molestation or annoyance caused by the injury to rivers or streams which receive

the *débris* discharged from the mines. For it is one of the inevitable consequences of hydraulic mining that not only is the æsthetic aspect of an entire region completely marred by its otherwise beautiful streams being converted into blood-red channels of dirt and silt, but it appears to be almost impossible for other industries, and especially that of agriculture, to be simultaneously carried on in proximity to the rivers (on which they have to depend for clean-water supplies) into which, or their tributaries, the *débris* discharged from extensively worked hydraulic-mines are thrown.

Although in Colombia, the mining laws oblige mine-owners to supply clean water to the extent necessary for such industries, and to replace that which is deteriorated, this entails large additional expense on the mine-owners, and the result is seldom so mutually satisfactory as to prevent litigation and the frequent temporary or possibly permanent suspension of the mines.

Another source of trouble, delay and expense is that caused by break-down of the water-courses in mountainous regions. The latter are frequently from 10 to 15 miles in length, and traversing as they generally do, every description of contour, from the alluvia of tropical jungle and forest to rocky precipice and ravine, the aqueducts are subject to constant attacks from torrential rains, landslides, and other agents of damage or destruction. On the other hand, where the expense of making a long ditch is not an obstacle, water-supplies are abundant, while native labour is usually efficient and plentiful, as well as cheap. The mining laws of Colombia are extremely liberal, there being no royalties or restrictions imposed by the government on the export of gold, and local taxation is comparatively light. There is, further, a great liberality, almost amounting to prodigality, in regard to the superficial areas conceded, and over which individual mining rights extend, affording facilities in these respects superior to those of many other countries.

The writer appends the following additional memoranda as being approximately applicable to gravel-mining in the Republic of Colombia. An average estimate of the cost of constructing a 500 miner's inches ditch, on an average grade of 10 to 12 feet per mile, is about £1,000 per mile, the cost of sluices being approximately 8s. per foot, more or less, according to the contiguity or otherwise of forest timber.

A frequent grade of 2½ feet wide by 3 feet deep sluices is about 5 inches in 10 feet, the size of the blocks is about 8 inches, and they are spaced 1 to 1½ inches apart. Should the sluice be of considerable length, usually the upper portion only is blocked, while the remainder, often extended as a tail-sluice, is paved with boulders. Generally speaking, the actual length of the sluice periodically cleaned depends upon the amount and quality of amalgam present in the blocked portion, to which the clean up, perhaps sometimes not exceeding 200 to 300 feet, is meanwhile limited. On commencing work, a run of two or three days is made without mercury, after which about 100 pounds are sprinkled into the first 300 feet of sluice, and 10 pounds a day of the mercury added subsequently during the remainder of the "run," the cleans-up being made fortnightly or monthly, according to the character of the gravel and other circumstances.

A miner's inch of water is understood to be the quantity flowing during 24 hours through an opening 1 inch square under a head of 6 inches. The Californian miner's inch is unfortunately not a fixed quantity. As a close approximation a miner's inch may be taken to be 1·6 cubic feet of water running per minute.

A cubic yard of gold-gravel weighs about 1·8 tons and a cubic metre about 2·35 tons. A pan of gravel contains about ½ cubic foot, or say 54 pans per cubic yard. A cubic yard of gravel contains about 100 batea-fulls.

About 35 average (prospector's) gold "colours" weigh 1 grain troy; 1 average "colour" per batea would be equivalent, therefore, to a yield of about 10 cents per cubic yard. The yield of the Tolima gravels ranges from about 10 cents to 25 cents or upwards per cubic yard.

The approximate working cost and expenses may be reckoned at from 5 to 10 cents per cubic yard. The percentage of gold contained in the amalgam from the sluices, before retorting, runs between 40 and 70 per cent., according to the coarseness of the gold and other circumstances. The quality of the melted bar-gold ranges from about 800 to over 900 fine, the remainder being chiefly silver. The mint value of standard gold of 22 carats, or 916·666 fine, is £3 17s. 10½d., and the Bank of England value is £3 17s. 9d. per troy ounce. Pure (fine) gold of 24 carats, or 1,000 fine, is worth £4 4s. 11·54d. the ounce troy, mint value, or £4 4s. 9·818d., say

£4 4s. 9¾d. per ounce (or 2·12 pence per grain) Bank of England value—each 0·001 fine being worth about 1d. The United States gold standard is 900 fine or 21·60 carats. A *castellana* (South America) of gold weighs 72·007 troy grains, and 1 ounce troy equals 6·6666 castellanas.

Prof. H. Louis (Newcastle-upon-Tyne), who had had opportunities of studying hydraulic mining and the gold-bearing gravels both of California and of Colombia, agreed with Mr. Gledhill in so far as that a close analogy lay between the Californian gravels and those of Colombia; and in many respects they were indistinguishable. He (Prof. Louis) could not from his own experience endorse the writer's comparison of "hydraulic" and "ground-sluicing," as he did not think that the loss in the tailings would in reality be so large as stated by Mr. Gledhill. Estimates of this kind were usually based upon preliminary estimates made at the mine, and these were apt to turn out exaggerations; the essential point to bear in mind was that they could work exceedingly cheaply with the hydraulic-monitor, whereas ground-sluicing was a comparatively costly operation. The hydraulicking operation was a commercial and not a scientific one, and if it were profitable to lose a certain amount of gold, when handling large quantities of gravel, it might nevertheless be the right process to adopt, because the cheap rate of working more than made up for any loss in the tailings.

Mr. W. N. Atkinson (H.M. Inspector of Mines) asked whether the loss of gold in the operation of dredging rivers in New Zealand and in New South Wales was as great as in the system of hydraulic mining.

Mr. James Stirling (Government Geologist of Victoria) remarked that in the colony of Victoria hydraulic working was not restricted to deposits of Pliocene age, but was also applied to Miocene, Pliocene and Pleistocene deposits. The character of the "wash" varied according to local conditions and the age of the deposit, but he did not think that the loss of gold by hydraulic sluicing was usually so great as stated by Mr. Gledhill. The gold in Colombia apparently occurred in three deposits of three ages, and was easily recovered, and under ordinary conditions of hy-

draulic sluicing, a considerable amount must pass away in the tailings. The interest of land-owners was being brought prominently before the mining authorities of Victoria, and statements had been made to a Royal Commission, that the tailings were polluting the rivers for 30 miles from the working-mines. Although there was not perhaps any striking analogy, there was some general resemblance between the hydraulic gold-fields of Victoria and Colombia.

Mr. E. GLEDHILL, with regard to the comparison between ground-sluicing and hydraulic mining under large volumes of water, said that he did not wish to imply that ground-sluicing would be the most remunerative method, but he merely wished to draw a comparison by showing the results obtained when using a comparatively small quantity of water. More gold was saved of the total amount present; and in proof of that, by largely increasing the quantity beyond a certain limit, the loss of gold was almost proportional to the increase of the quantity of water employed. To bring home this point; in his own opinion (having upwards of 1,000 inches of water) rather than use that quantity of water in one monitor, he would divide it into two or three streams and reduce the quantity flowing down any one sluice.

Dredging had been attempted in Colombian rivers, but hitherto the results had not been altogether successful; the dredgers did not seem to be able to search sufficiently into the bottom of the rivers, where they had been tried. Unless the bed-rock itself could be reached by the dredger, and so scraped by it as to enable the particles of gold existing in the holes and irregularities of the rocky bottom to be laid hold of, he did not think that, generally speaking, gold-dredging in Colombia would be financially satisfactory. Having an abundantly auriferous river-bottom, he would prefer, where that were possible, to divert the stream, and by ground-sluicing, or otherwise, wash out the gold from the comparatively dry river-bed. In large rivers, this could not of course be practically accomplished, and it would then become a question of trial and experiment as to whether those portions of the river-bottom actually capable of removal by the dredger, although not containing the bulk of the gold of the river, were remunerative or otherwise.

The CHAIRMAN (Mr. H. C. Peake) moved a vote of thanks to Mr. Gledhill for his interesting paper.

Mr. M. WALTON BROWN seconded the vote of thanks, which was cordially approved.

The following paper by Mr. J. J. SANDEMAN on "Gold-Mining in the Rossland District, British Columbia," was read as follows:

GOLD-MINING IN THE ROSSLAND DISTRICT, BRITISH COLUMBIA.

By J. J. SANDEMAN.

Rossland, British Columbia, is situated in the West Kootenay district, and from a geological and mineralogical point of view it forms a study of great interest. The present site of the town of Rossland was at one time the crater of a volcano from which lava and ashes deluged the surrounding country. The variety of igneous material which covers the district seems to intimate that the eruptions were intermittent and that the volcano itself was of great age. The occasional presence of quartzite or metamorphosed sandstone seems to indicate that a shallow sea existed here, previous to the volcanic outbreak. The district may be roughly described as an area of gabbro, surrounded by quartz-diorite so highly metamorphosed that the contacts are very indistinctly defined. The gabbro area, though only about 1½ miles wide, by 4 or 5 miles in length, is one of great importance to the district; for it is in the gabbro, or closely bordering it, that the best mines have been discovered. The Gertrude mine appears to be the only exception from this rule, for 200 feet below the surface, the top of a gabbro-dyke has intruded and scattered what had promised to be a fine body of ore.

Many erroneous local conjectures have been made about the age of this district. Fossils have been found which geologists declare belong to the Carboniferous period; these, however, serve only to prove that at some time Carboniferous strata had overlain the present igneous rocks and had been subsequently removed, probably by glacial agencies. The writer has, so far, been unable to obtain any data proving that the fossils have been found in any other location than near the surface or in the upper part of fissures.

Another local controversy has greater justification, and this difference of opinion is in regard to the nature of the faulting which has so much disturbed and contorted the district. Compression or the shear-zone theory, and elevation and depression

have each their supporters. But any engineer who strictly adheres to either theory will soon find himself at fault in more senses than one, for each has been controverted by practical experience. In the writer's opinion, the complex faulting is owing to the following historic sequence of geology:—This district, in conjunction with the rest of the Pacific coast has been subjected to a great upheaval with consequent faults and general weakening of the surface-crust. A great thrust from the west probably started the volcanic activity, and the enormous mass of igneous material, removed from below and precipitated on the surface, reduced the support and greatly increased the weight—hence a general subsidence took place, with its accompanying normal faults. The cooling of this great mass caused shrinkage and compression, and has caused some of the shear-zone phenomena, but the consequent parallel fissures and reversed faults have been intersected and cut off by previous faulting.

The veins are true fissure-veins, the metal in them being the result of metalliferous liquids flowing through them, attacking the country-rock on each side, dissolving the rock and gradually replacing it with metallic sulphides. Such being the case, the shoots of ore often fade away into the surrounding country-rock and there being no well-defined walls the ore is frequently lost. This, with the very irregular width of the veins and their complex faulting renders Rossland geology an exceedingly difficult problem to mining-engineers. Yet, the writer has proved by actual practice that these difficulties may be overcome by careful study; but the conservative mining-engineer with fixed ideas, formed from experience in other districts, would soon convert a mine into a worthless hole in the ground.

The principal ores are chalcopyrite and pyrrhotite carrying various percentages of gold, silver, copper and bismuth, but although some ore will run to a total value of £10 per ton, the majority is of so low a grade that only the abundant facilities of transportation and the comparatively low cost of smelting would justify mining in such a country.

The diorite-formation is intensely hard and expensive to work, but fortunately the water is easily handled.

At the present time, Rossland is under a cloud, and the constant friction between the Miners' Union and the companies has ended in several large mines being closed. In each case, the com-

panies attribute this cessation of work to defective machinery; although the writer has no authority for questioning this statement, judging from his own experience, the hoisting and drilling-plants in the district are unusually good. Electricity is the motive power, the West Kootenay Company supplying by cable-transmission, power to run the dynamos at the mines at a cost about 50 per cent. less than the same work could be done by steam; this, with the various works lighted by electricity, gives the district a very business-like appearance, and the surrounding mountains with their railroads and self-acting trams tipping into the railroad-trucks all bear evidence of practical and economical work.

As it is possible that members of the Institute might be in a somewhat similar district to this, the writer will point out a few matters that might be of use. First, where chalcopyrite changes into pyrrhotite the continuation of the ore is pretty well assured; on the other hand, where pyrrhotite changes into chalcopyrite it is likely soon to scatter out among the enclosing rocks. When a lode gives out and leaves no visible trace, small and sometimes almost invisible streaks of calcite frequently follow the strike of the lode or run parallel with it. Once, by following one of these streaks a few feet, and then cross-cutting, the writer found ore where it would otherwise have been certainly missed. The inflow of water in underground workings is no sign of vicinity to a lode, but rather the reverse. Where water proves troublesome, a cross-cut intersecting the water-flow and conducting it to the nearest fault-line will sometimes act as a drain and save much hoisting. Where the gangue of a lode becomes siliceous, the quartz, though apparently worthless, frequently monopolizes all the gold-values. The more valuable quartz is clouded by a dark-grey substance: these stains are probably caused by some form of petzite, this, however, is merely a surmise, for the quartz on assay yields no trace of tellurium.

The CHAIRMAN (Mr. H. C. Peake) moved a vote of thanks to Mr. Sandeman for his interesting paper.

Prof. H. LOUIS seconded the resolution, which was cordially approved.

Mr. H. G. W. HALBAUM's paper on "The Theory of the Equivalent Orifice treated Graphically" was read as follows:—

THE THEORY OF THE EQUIVALENT ORIFICE TREATED GRAPHICALLY.

By H. W. G. HALBAUM.

This paper makes no claim to originality, unless it be originality of treatment, and the theory is essentially that of Mr. D. Murgue. The writer will attempt to simplify the formulæ pertaining to the theory of the equivalent orifice, and show the laws affecting the problem in the clearest manner. He proposes to show that the whole theory may be fully explained and illustrated by the properties of the circle, which is the simplest of all curves, and the most easily constructed. It is not necessary to expound the theory in detail; it has recently been re-stated by Mr. Walton Brown, and his report on "Mechanical Ventilators" may be referred to for a full exposition. It is not necessary to discuss the limitations of the theory, or the difficulties connected with obtaining accurate measurements of pressures and volumes. In the meantime, as Mr. Murgue's theory is widely accepted—and there is nothing better to put in its place—it is no waste of time to ask whether his theory cannot be re-cast in a simple mould, and so rendered more generally useful.

The equivalent-orifice theory is essentially one of ratios, and all constants appearing on both sides of equations, and encumbering the calculations without affecting the ratios, will be ignored. It will also be assumed that figures correct to 1 per cent. are sufficiently correct for practical purposes, and, in order to keep the figures within reasonable dimensions, the writer will follow the late Mr. J. J. Atkinson's sensible method of stating volumes and velocities in thousands of units. There is one refinement, however, which it is necessary to retain, namely:—the expression of air-pressures in feet of air-column. Mr. Walton Brown's report upon "Mechanical Ventilators" shows that the weight of a cubic foot of air in the fan-drift may vary from 0·069 to 0·078 pounds. Thus any general assumption that a given figure represents "normal densities" might

lead to errors of 15 per cent. in particular cases. In this paper, therefore, the velocity, u, is measured in thousands of feet per minute; the volume, V, in thousands of cubic feet per minute; and the pressure, h, which produces the volume, V, is the pressure measured in, h, feet of air-column having the same density as the air in the volume, V.

The pressure created by a fan is a function of the tangential velocity, u, and the theoretical pressure is

$$T = \frac{u^2}{g} \times \frac{1{,}000{,}000}{3{,}600}; \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The simplest expression of this formula for practical use appears to be

$$T = \frac{70u^2 - u^2}{8} = \frac{u^2(70-1)}{8} \quad . \quad . \quad (2)$$

But the imperfections of the fan prevent it from developing the theoretical pressure, and the total pressure actually developed is

$$H = kT; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

k, being the first fan-constant, which may be defined as the coefficient of the theoretical pressure.

The total pressure, H, or the initial pressure of Mr. Murgue, is expended in two directions. One part, h, is the effective or ventilating pressure, and is expended in overcoming the resistance of the mine to the passage of the air. This part is visible, or, rather, it is supposed to be made visible by the water-gauge in the fan-drift, or inlet, as the case may be. The other part of H is h_0; it is not visible on the water-gauge, but it is expended on passing the air through the fan against the resistance offered by the fan. Therefore, the effective pressure ventilating the mine is

$$h = H - h_0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Thus the effective ventilating pressure is greater when h_0 is less, if H be constant. This formula may also be written as $H = h + h_0$. Now, as in any right-angled triangle the square of the hypotenuse is equal to the sum of the squares on the other sides, we recognize that $\sqrt{H}$, $\sqrt{h}$ and $\sqrt{h_0}$ continually sustain to each other the relation of the hypotenuse, the base and the perpendicular of a right-angled triangle. If this triangle be constructed, and the angle opposite $\sqrt{h_0}$ be ϕ degrees, we can write formula (4) thus:— $h = H - H \sin^2\phi$; or $h = H(1 - \sin^2\phi)$. This formula is the counterpart of Mr. Murgue's equation of the straight line, with the difference that it is simple and manageable It is now evident

that the relation of h and h_0 is that of $\cos^2\phi$ and $\sin^2\phi$, as $1 - \sin^2\phi = \cos^2\phi$. Therefore,

$$h = H\cos^2\phi \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and

$$h_0 = H\sin^2\phi \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

It is a law of fluid-motion that the resistance varies as the square of the velocity, and the ventilating-pressure necessary to pass a given volume measures the resistance of the mine to the passage of the given volume. Other things being equal, if V varies, h varies as V^2. Thus, for the same mine—and by the same mine is meant the same equivalent orifice—V^2/h = constant. This constant is the true mathematical coefficient of the resistance, because the resistance, h, is constant only so long as the mine is constant. It is, however, more convenient to use the square root of the constant instead of the constant itself. Let M be that square root, then

$$M = \frac{V}{\sqrt{h}}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and M is constant for the same mine.

Within certain limits, the same reasoning applies to the fan. It applies when the volume, V, of air dealt with by the fan, equals the volume of air passing through the fan and equals the volume of air passing through the mine. If these equalities do not obtain, the theory becomes unworkable and useless. But the theory assumes that they do obtain; then, k being the first constant for the fan, the second constant

$$F = \frac{V}{\sqrt{h_0}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The problem now is to find the law that determines what volume any fan, whose constants are k and F, will produce on various mines, whose respective constants are M_1, M_2, M_3, and so on. It may be noted that M is $\frac{5}{16}$ of Mr. Murgue's equivalent orifice, and F is $\frac{5}{16}$ of his orifice of passage. Those who desire to correlate may do so, but, in the opinion of the writer, it is unnecessary. M and F are the coefficients of $\sqrt{h}$ and $\sqrt{h_0}$ respectively; and the equations (7) and (8) show the shortest methods of determining their values.

If the value of M in equation (7) be divided by the value of F in equation (8) we obtain

$$\frac{M}{F} = \sqrt{\frac{h_0}{h}}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

and substituting in equation (9) the values of h and h_0 shown by equations (5) and (6), we have

$$\frac{M}{F} = \frac{\sin\phi}{\cos\phi} = \tan\phi; \text{ and}$$
$$M = F\tan\phi. \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

We now come to the consideration of the volume of air that the fan will produce on any mine whose constant is M. By equation (8), $V = F\sqrt{h_0}$, and by equation (7), $V = M\sqrt{h}$. Taking the last of these values, $V = M\sqrt{h}$, and substituting the value of h, from equation (5), then $V = M\sqrt{H}\cos\phi$; and inserting the value of M from equation (10), we obtain $V = F\tan\phi\sqrt{H}\cos\phi$; but $\tan\phi\ \cos\phi = \sin\phi$. Therefore,

$$V = F\sqrt{H}\sin\phi. \quad . \quad . \quad . \quad . \quad . \quad (11)$$

The same result, of course, follows, if the value of V in equation (8) be taken, for it is then only necessary to substitute the value of h_0, as shown in equation (6).

The power in the air is similarly influenced by the magnitude of the angle ϕ; thus while the volume is zero at 0 degrees and attains its maximum at 90 degrees, and the ventilating-pressure has its maximum at 0 degrees and its zero at 90 degrees, the power in the air is *nil* at both points; because the factors of ρ, the power in the air, are h and V; and one or other of these values is zero at either end of the quadrant. The power, ρ, reaches its maximum at 35 degrees 16 minutes of angle; because ρ varies as hV; and, $hV = H\cos^2\phi F\sqrt{H}\sin\phi$; in which F is a constant factor in the case of the same fan, and H is constant at the same speed. Hence, at the same speed,

$$\rho \text{ varies directly as } \cos^2\phi\ \sin\phi, \quad . \quad . \quad . \quad (12)$$

and the product of the sine and the squared cosine attains its maximum at an angle of 35 degrees 16 minutes. At this point, $M = 0{\cdot}7071F$; or $F^2 = 2M^2$; the ventilating-pressure is two-thirds of the initial pressure, H, and the volume of air is about 58 per cent. of its theoretical maximum. Consequently, the angle of maximum power in the air, consistent with the given speed, is 35 degrees 16 minutes.

The law, therefore, of the volumes, the effective pressures and the powers in the air, which a given fan will produce on different mines of varying resistance is the same as the law of the variation and mutual interdependence of the sines, cosines and tangents of varying angles. For the same fan, at the same speed, running on mines of various resistances, $h \div \cos^2\phi$, equals the constant, H; $V \div \sin\phi$, equals the constant, $F\sqrt{H}$; $\rho \div (w\cos^2\phi \sin\phi)$ equals the constant, $F\sqrt{H^3}$, multiplied by a numerical constant, (the reason and meaning of w will be shown presently); and, $\tan\phi$ equals $M \div F$.

It will now be evident that the natural characteristic curve, or the curve of volume, carried from M = zero, to M = infinity, is but the arc of 90 degrees in a circle whose radius is, according to equation (11), of a length equal to $F\sqrt{H}$; because the ordinate of the volume is a constant multiple of $\sin\phi$, and the sines are continually limited by the circumference of the circle. It is true that, plotted by the ordinary method, introduced by Mr. Murgue, the curve does not become circular, because the ordinary method is to plot the volumes and the equivalent orifices, or the values of V and M, as co-ordinates. In other words, it plots the sines at right-angles to the tangents, instead of plotting them as parallel lines, or as lines diverging at the same angle as the angle of the arc to which they belong. The circular arc, or the natural curve of volumes gives precisely the same information with infinitely less trouble. The curve is still "characteristic," for it is characteristic of the radius describing it, and this radius is supplied by the fan. But having the radius, the curve itself can give no further information beyond that already contained in mathematical tables.

It is also easy, from the geometrical standpoint, to see the philosophy of the equation of the straight line which Mr. Murgue pronounces an "excellent verification" of his theory. The straight line is obtained by plotting V^2 and h as co-ordinates; but this is merely plotting the values of $\sin^2\phi$ upon those of $\cos^2\phi$, and $\sin^2\phi$ is the arithmetical complement of $\cos^2\phi$, whatever be the value of ϕ. Hence the one ordinate can rise only at the expense of the other, and nothing but a straight line can possibly be obtained under such circumstances. As a matter of fact, all the points thus obtained lie in the chord of 90 degrees, for the simple reason that the sum of the ordinates must always be equal to the radius. In

the remaining curve, introduced by Mr. Murgue—that which shows the fall of the effective depression as the mine is enlarged—the ordinates and co-ordinates reduced to their lowest terms are $\tan\phi$ and $\cos^2\phi$.

All that is required, therefore, is to determine the value of F for the fan, and the only difficulty is the common difficulty of obtaining really accurate measurements of h and V. (1) Let the fan be run on the ordinary mine at uniform speed, the volume produced will be V, and the effective depression or ventilating-pressure will be h; and (2) let the separation-doors be opened and the fan run at the same speed, the volume will now be $V+x$; and the ventilating-pressure will fall to $h-y$. Since both u and H are constant, the sum of h and h_0 will be constant; and if the ventilating-pressure has fallen by the amount y, the useless pressure h_0, has risen by precisely the same amount. Hence (still retaining the symbols of V, h and h_0 for the volume and pressures obtained on the ordinary mine) the values may be equated by (8), and we obtain $V = F\sqrt{h_0}$ for the ordinary mine; and $(V+x) = F(\sqrt{h_0+y})$ when the separation-doors are open. Then $(V+x)-V = F(\sqrt{h_0+y}) - F\sqrt{h_0}$; and

$$F = \sqrt{\frac{x(2V+x)}{y}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

The same formula (13) may be expressed in a way that looks still simpler because $x(2V+x)$ is the difference of the squared volumes, therefore

$$F = \sqrt{\frac{\text{Difference of squared volumes}}{\text{Difference of pressures}}}.$$

But the equation (13) is really the simpler formula, as it shows at a glance that there is no necessity to square the volumes, or to deal with such masses of figures as are commonly employed in these investigations.

The value of F being found, that of M is determined by equation (7), and the tangent of the angle ϕ (whether that obtaining when the fan acts on the ordinary mine or otherwise is immaterial so long as the other values are correlative) is then found by equation (10).

The angle ϕ being thus disclosed, the value of k may be found in several ways, and perhaps the most convenient is to find it thus:—By equation (3), $k = H \div T$; and by equation (5), $H = h \div \cos^2\phi$, whence

$$k = \frac{h}{T \cos^2\phi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

The value of h may be observed, and that of T may be calculated from the tangential velocity of the fan, by the rule embodied in equation (2). The reliability of the results, of course, will depend on the correctness of the observations.

We thus get the characteristic constants of the fan, and we can predict what the fan will produce on any mine, where M bears a reasonable proportion to F. On any such mine, the fan at any speed, u, will produce a ventilating-pressure equal to

$$h = \left(\frac{70-1}{8}\, k\right) u^2 \cos^2\phi; \quad . \quad . \quad . \quad . \quad (A)$$

and the quantity within brackets is constant for this fan. And on any such mine, the fan will produce a volume equal to

$$V = (2{\cdot}94F\sqrt{k})u \sin\phi; \quad . \quad . \quad . \quad . \quad (B)$$

and the quantity within brackets is also constant. And the useful horse-power in the air will be

$$\rho = (0{\cdot}77F\sqrt{k^3})wu^3\cos^2\phi \sin\phi; \quad . \quad . \quad (C)$$

in which w is the weight in pounds of a cubic foot of air at the density of the volume, V, and where the quantity within the brackets is constant. Each of the quantities within brackets can, when F and k are known, be reduced to a single numerical value, and these values might be called, respectively, the pressure-constant, the volume-constant, and the power-constant, for that particular ventilating-machine.

It will be noted that the pressure, h, which is measured in feet of air-column, varies only as $u^2\cos^2\phi$; that the volume, V, varies only as $u \sin\phi$; the density of the air makes no difference, because the velocity u always corresponds to a given height of air-column, without reference to its weight. And the squared volume, V^2, varies as the height of h and not as the weight of h, because the density of the air in the column, h, is the same density as the flowing air in the volume, V. Therefore, in order to reduce the water-gauge to feet of air-column, the height of air-column corresponding to the water-

column must be estimated from the density of the flowing air in the volume, V. Thus, in order to obtain accurate results in these matters, it is indispensable that the density of the air be measured where V is measured. Otherwise V and h will not correlate with each other, because the pressure would be measured in feet of air-column which is not of the same density as the flowing air. An oversight of this kind may, under ordinary circumstances, introduce errors of 10 per cent. If one observer measures the volume, V, in a cool downcast shaft, while another measures the volume, V, in a warm upcast shaft, the first observer will obtain a lower value for V than the second. And if each value of V be divided by the square root of the water-gauge, reduced to the value of h denoted by the density of the air at a common spot, each observation will record a different value of M, or a different equivalent orifice for the same mine. But if the water-gauge measured in the downcast be reduced to feet of air-column of the same density as the air in the downcast shaft, and if the pressure in the upcast shaft be reduced to feet of air-column of the same density as the air in the upcast shaft, then $V \div \sqrt{h}$ measured in the downcast shaft equals $V \div \sqrt{h}$ measured in the upcast shaft; and the value of M deduced from data obtained in one part of the mine will be equal to the value of M deduced from data obtained in any other part of the mine. This reasoning clearly shows that the right place to measure the density of the air is the place where the volume of air is measured.

It will be noted, however, that in the formula (C), the weight of air is a factor in the power of the ventilation. On the same mine, at any given speed, u, the fan will develop a given pressure, h, and a given volume, V. But if the density of the given volume of air is less, the density of the column h is less, hence the water-gauge will be less, in fact the whole kinetic energy of the ventilation will be less; because, although the given volume is the same, the weight of the volume is less. Hence the power required to put the given volume into motion is less, and the horsepower in the ventilation will vary with the density of the air although the volume of air remains the same. This seems to be a rather interesting aspect of the case which has not yet received its share of attention, for u being the same, and V the same, the horsepower in the ventilation will vary directly as the density of the air. Now, the density of the air varies within rather wide limits on the surface, but still more so between one mine and another. The tables attached to Mr. Walton Brown's report on "Mechanical

Ventilators"* show that the weight of the air at one time and place may be 15 per cent. greater than its weight at another time and place. And 15 per cent. added to or subtracted from the numerator of the fraction, which denotes the mechanical efficiency of the fan, is an important error, when we consider that the density of the air is a matter over which neither the maker of the fan nor the user of

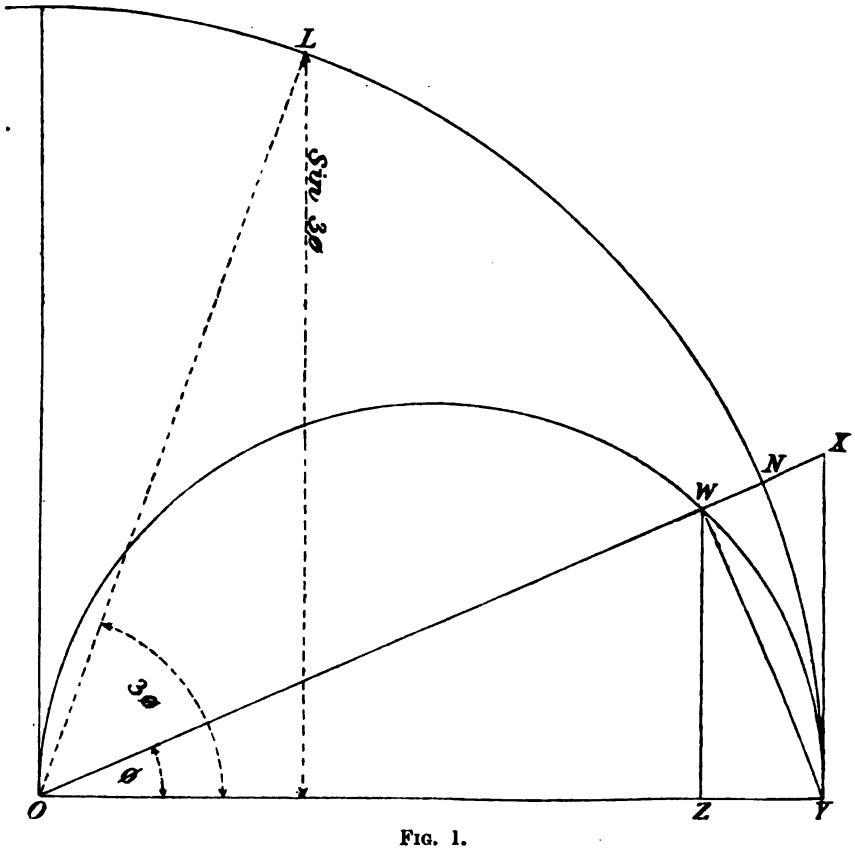


FIG. 1.

it has any control. It would thus be very easy, in a comparative test of two fans to so choose one's times and places that the worst fan should be given every chance to prove itself (apparently) the better machine. It is true, however, that the influence of the density would also affect the denominator of the useful effect, although not to the same extent as it affected the numerator.

* *Trans. Inst. M.E.*, vol. xvii., page 521.

One or two conclusions follow very clearly from the three formulae, A, B and C. At the same speed, u, and the same angle, ϕ, the given fan will always develop the same height of air-column, h; but not always the same height of water-gauge; and u and ϕ being constant, the fan will always give the same volume, V, but not always the same useful power, ρ. This apparent anomaly, of course, arises from the custom of measuring the volume, V, in cubic feet instead of in pounds.

The consideration of greatest importance, however, is that the geometrical method allows one to obtain results by mere plotting which would otherwise only be obtainable by a great expenditure of labour. Fig. 1 shows the law of the variation of volume and pressure with the resistance of the mine. This figure shows the simplest case, in which $F=H=F\sqrt{H}=1$. Then $OY=1$; and the value of M being XY; the volume will be WY; the ventilating pressure, OZ; and the useless pressure, YZ; while the arc, LNY, is the curve of volumes. It is evident, if $OY=1$, that $XY=\tan\phi$, the ratio of M; $WY=\sin\phi$, the ratio of V; $OZ=\cos^2\phi$, the ratio of h; and $YZ=\sin^2\phi$, the ratio of h_0.

$$\text{Because } \cos\phi = \frac{OW}{OY} = \frac{OZ}{OW}; \text{ therefore } \cos^2\phi = \frac{OW}{OY} \times \frac{OZ}{OW} = \frac{OZ}{OY}$$

But, $OY=1$; therefore $\cos^2\phi=OZ$. Similarly, it can be proved that $YZ=\sin^2\phi$; and however XY, the ratio of M, may be extended, the perpendicular let fall on OY from the point where the radius of LNY intersects the semicircle, OWY, will cut OY into $\cos^2\phi$ and $\sin^2\phi$, or in other words will cut off the useless depression, h_0, from the initial depression, H, and leave the effective depression between O and Z.

The variation of the power (apart from atmospheric factors), may be plotted in the same graphic manner. For ρ varies as $\cos^2\phi \times \sin\phi$. But $\cos^2\phi \times \sin\phi = (\sin 3\phi + \sin\phi) \div 4$ Consequently, no awkward multiplications, etc. need be performed, because the useful power in the ventilation varies as the sum of $\sin\phi$ and $\sin 3\phi$, and may, like the value of $\cos^2\phi$, be measured on Fig. 1. No doubt, in practice, F is never equal to H, and therefore the problem is not quite so simple as Fig. 1 assumes. Still, the extra difficulty is no greater than the extra difficulty attaching to drawing two concentric circles instead of one.

As an illustration, the writer has constructed a diagram of the work performed by the Créal ventilator on five different mines or equivalent orifices. The figures are given by Mr. Murgue; and the way in which those figures arrange themselves in geometrical order is shown in Fig. 2 (Plate XVIII.). In order that the plotted results may be compared with Mr. Murgue's figures, the values of the equivalent orifices are plotted (a_1, a_2, a_3, a_4 and a_5) as tangents on the circle, whose radius is the orifice of passage. The rest of the diagram calls for no remark, and the decimally differing scales of the drawing have been chosen so that the identity of the plotted values with Mr. Murgue's figures may be instantaneously proved by running off the lines with a 40-parts-to-1-inch scale. Mr. Murgue's table of results* obtained from the Créal fan is as follows:—

No. of Experiment.	Equivalent Orifice.	Speed of Rotation per Minute.	Volume of Air per Second.	Observed Depression.	Calculated Depression.	Difference.	Squared Volumes.
	Square Ft.	Revolutions.	Cubic Feet.	Inches.	Inches.	Inches.	
1	6·604	63·66	298·82	1·0598	1·0582	+0·0016	89,283·39
2	9·985	,,	442·45	1·0183	1·0193	−0·0010	195,766·00
3	12·199	,,	532·16	0·9866	0·9873	−0·0007	283,194·46
4	14·846	,,	635·99	0·9452	0·9428	+0·0024	404,483·28
5	20·922	,,	839·31	0·8314	0·8308	+0·0006	704,441·28

Mr. Murgue gives the orifice of passage for the Créal fan at 37·87 square feet, and the initial depression at the speed named as 1·0908 inches. The straight-line equation for the same ventilator is stated to be:—

$$h = 1{\cdot}0908 \text{ inches} - 0{\cdot}000{,}000{,}365 V^2.$$

If these figures be compared with the plotted values of Fig. 2, it will be found that the divergence never rises to 1 per cent. or anything like it. And the work that the Créal ventilator will produce on any other equivalent orifice can be ascertained by merely drawing a new radius to the new tangent, and dropping perpendiculars on the base-line from the intersections of the radius with the curve of volumes and the semicircle of pressures. It will hardly be disputed that $h = H\cos^2\phi$ is an infinitely more convenient formula than $h = H - 0{\cdot}000{,}000{,}365 V^2$.

The geometrical method also throws considerable light upon the problem of mechanical efficiency, and points out how one may

* *The Theories and Practice of Centrifugal Ventilating-Machines*, by Mr. D. Murgue, [translated by Mr. A. L. Steavenson, 1883], page 28.

locate the angle at which a given fan will develop its maximum useful effect. But there are several pros and cons about this question that can hardly be passed by without discussion, and the writer will defer the consideration of the mechanical efficiency to a future occasion.

In the meantime, it may be advisable to collect the straggling formulæ advanced in this paper, and summarize the conclusions, which, in principle, be it remembered, are strictly those of Mr. Murgue.

SUMMARY.

The theoretical pressure due to a perfect fan moving with a tangential velocity, u, in thousands of feet per minute, is, in feet of air-column :—

$$T = \frac{u^2(70-1)}{8}.$$

The total pressure actually developed is :—

$$H = kT,$$

and k is constant for the same fan.

The effective pressure or the pressure ventilating the mine is h, the pressure expended within the fan is h_0, and $\sqrt{H}$ is the hypotenuse of a triangle whose base is $\sqrt{h}$ and whose perpendicular is $\sqrt{h_0}$. Therefore :—

$$H = h + h_0 ;$$
$$h = H\cos^2\phi ; \text{ and}$$
$$h_0 = H\sin^2\phi.$$

M^2 is the coefficient of the mine-resistance to the passage of the volume, V, in thousands of cubic feet per minute, and

$$M = \frac{V}{\sqrt{h}}.$$

F^2 is the coefficient of the fan's resistance, and

$$F = \frac{V}{\sqrt{h_0}} ;$$

but $$\frac{M}{F} = \frac{\sqrt{h_0}}{\sqrt{h}} ;$$

therefore $$M = F\tan\phi ;$$

and F is constant for the same fan.

Because $$V = F\sqrt{h_0} ;$$

therefore $$V = F\sqrt{H}\sin\phi ;$$

and $F\sqrt{H}$ is constant for the same fan at the same speed.

The useful power, ρ, in the air varies as $h\,V$, when other things are constant, but $h\,V$ varies as $\cos^2\phi\,\sin\phi$, therefore:—

ρ varies as $\cos^2\phi\,\sin\phi$.

But $\cos^2\phi\,\sin\phi$ attains its maximum when ϕ equals 35 degrees 16 minutes; therefore at any given speed

ρ attains its maximum when $M^2 = \frac{F^2}{2}$; or when $M = 0{\cdot}7071\ F$.

If, at the same speed, the fan be first run on the ordinary mine, and then with the separation-doors open, the difference of the volumes will be x thousand cubic feet per minute, and the difference of the ventilating-pressures will be y feet of motive column. If the smaller volume be V in thousands of cubic feet, then

$$F = \sqrt{x\,\frac{(2V + x)}{y}} = \sqrt{\text{sum of the volumes} \times \frac{x}{y}}.$$

The tangent of the angle ϕ may be found thus:—

$$\tan\phi = \frac{M}{F};$$

$$\text{and } k = \frac{H}{T} = \frac{h}{T\cos^2\phi}.$$

$$\text{Let } a = \frac{69k}{8};$$

then a is constant for the same fan, and on any mine at any speed, the fan will produce a ventilating-pressure equal to

$$h = au^2\cos^2\phi,$$

the angle ϕ varying with the mine.

$$\text{Let } b = 2{\cdot}94\ F\sqrt{k};$$

then b is constant for the same fan, and on any mine, at any speed, at any value of M, and at any angle ϕ, the volume delivered by the fan will be V thousands of cubic feet per minute, and

$$V = bu\,\sin\phi.$$

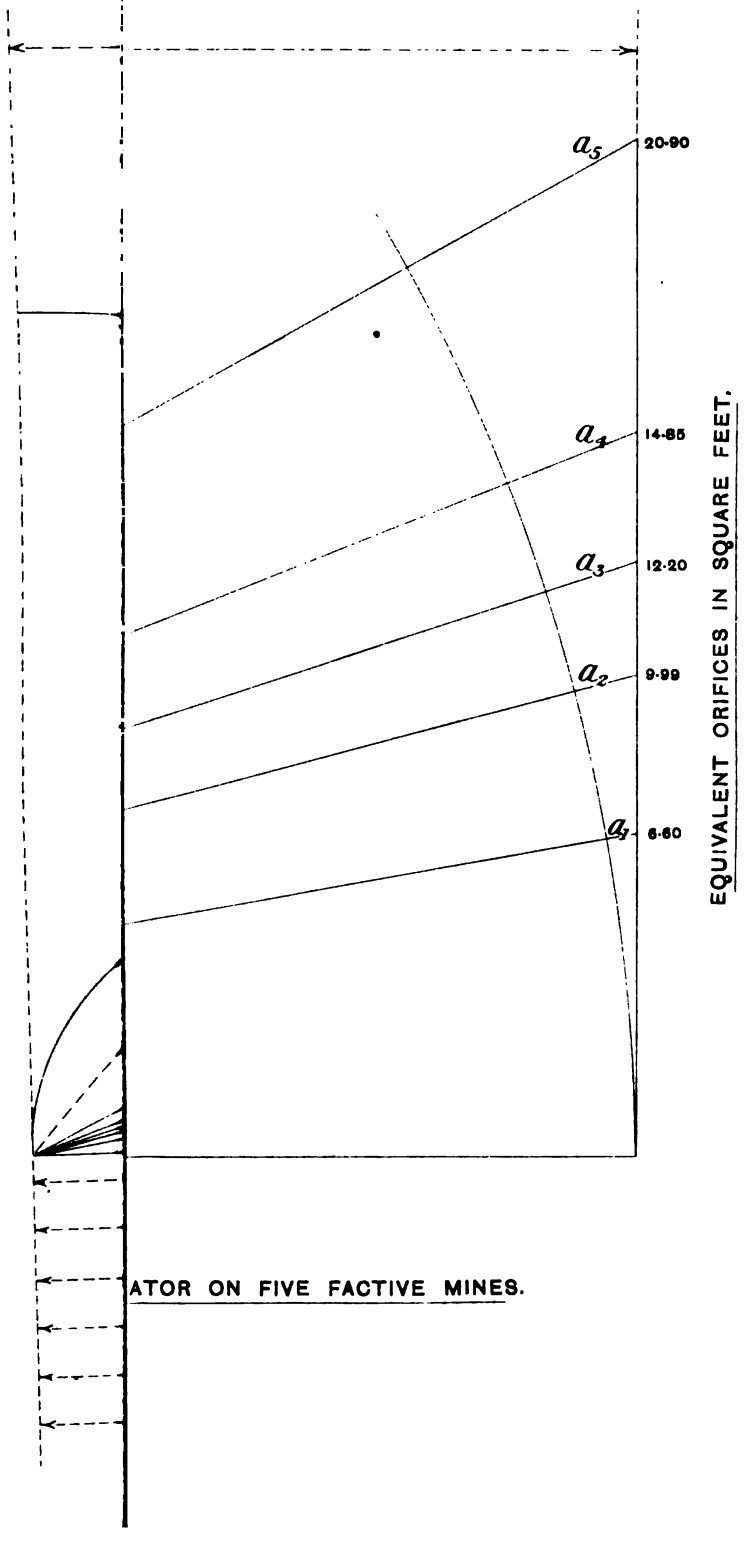
Let w be the weight of a cubic foot of air of the volume, V, and let

$$c = 0{\cdot}77F\sqrt{k^3};$$

then c is constant for the same fan, and on any mine, at any speed, at any value of M, and at any angle ϕ, the useful power in the air developed by this fan will be equal to ρ horsepower, and

$$\rho = cwu^3\,\frac{\sin\phi + \sin 3\phi}{4}.$$

The radius of the semicircle of pressures is $a \div 2$; the radius of the curve of volumes is b; and the radius of the circle of power is c. The curve of volumes and the circle of power are concentric,



ATOR ON FIVE FACTIVE MINES.

and their centre lies on the circumference of the circle of pressures. Thus, to determine what any fan whose constants are F and k will produce on mines whose resistance-coefficients are M_1, M_2, M_3, M_4, etc., it is only necessary to revolve a radius round a given centre and note the heights of the intersections.

It will, of course, be understood that a is the diameter of the semicircle of pressure, and b the radius of the curve of volume, when $u = 1$. At any other speed, the true diameter H of the pressure curve is $a \times u^2$; the radius of the volume is $b \times u$; and similarly, the absolute radius of power is $c \times wu^3$. But a, b and c are, according to the theory, constant for the same fan at all speeds on all mines; and they alone are the differentiating factors which distinguish the radii of pressure, volume and power possessed by one fan from the radii of pressure, volume and power possessed by any other machine. Knowing a and b, the theoretical quantities are known; by plotting the angle ϕ, the ratio of the actual to the theoretical is measured off; and the ratio is converted into an equality by multiplying by wu^3, u^2 or u, as the case may be.

Of course, the writer does not state that there will never be any discrepancies, as he recognizes the great difficulty of measuring volumes and pressures with absolute accuracy; but it is merely pointed out that Mr. Murgue's results can be obtained with a tithe of the labour usually expended. The writer hopes at some future time to show the application of the theory to the problem of the mechanical efficiency of the fan, in so far as that is affected by the varying resistance of the mine and the varying density of the air.

Mr. Daniel Murgue (St. Etienne) wrote that he must acknowledge that Mr. Halbaum's graphic method was a very ingenious, faithful and clear explanation of the theory of the equivalent orifice. Mr. Halbaum's representation by geometrical lines of the depression, of the volumes and of the equivalent orifice makes easily apparent the connexion of these different dimensions, and Mr. Halbaum rendered a real service to engineers preoccupied with the good ventilation of their mines. He (Mr. Murgue) could only approve of the reserve of Mr. Halbaum on the subject of the discrepancies that sometimes happen experimentally in observations. The experiments upon the Créal ventilator yielded very concordant results, which must be especially attributed to the

fact that for each experiment the position of the sliding-shutter was regulated so as to afford the maximum volume of air. When the sliding-shutter is fixed, the straight line $h = H - MV^2$ could not be drawn with exactness.

The Rev. G. M. CAPELL (Passenham) wrote that Mr. Halbaum had originated a theory of great utility and accuracy, which would be very useful to all experimenters upon ventilating-fans.

Prof. HENRY STROUD (Durham College of Science, Newcastle-upon-Tyne) wrote that Mr. Halbaum's paper, so far as the graphical portion was concerned, seemed ingenious, and would no doubt form a useful addition to the literature of the subject of mechanical ventilators. The author's statement that "it would thus be very easy, in a comparative test of two fans to so choose one's times and places that the worst fan should be given every chance to prove itself (apparently) the better machine," seemed strange to him, and he asked whether this statement was intended to apply to published experiments.

Mr. H. W. HALBAUM, replying to the discussion, wrote that in expressing a certain amount of reserve, he merely wished to avoid committing himself to anything lying outside the strict area covered by his paper. He had no desire in any way to appear to depreciate the theory propounded by Mr. Murgue, but he did recognise the great necessity of conducting experiments with the most scrupulous care, if the results obtained were to be consistent with each other and with the theory of equivalent orifices. He agreed with Mr. Murgue that the experiments on the Créal ventilator gave concordant results, and he agreed with Mr. Murgue in thinking that the proper adjustment of the sliding-shutter was an important factor in the case. It was, indeed, the recognition of these essential details that led him (Mr. Halbaum) to speak somewhat reservedly with respect to the precise area over which the theory of equivalent orifices might be supposed to apply. It was very easy to overlook some of the conditions which the theory presupposed, and if these were overlooked, the results would be inconsistent and misleading. The reserve referred to by Mr. Murgue implied the recognition of this danger, but it implied no more than that, so far as he (Mr. Halbaum) was concerned. He was afraid, however, that Mr. Capell had paid him

a compliment he hardly deserved: he had certainly not originated any theory of his own, but he had only attempted to re-cast the theory of Mr. Murgue in a simpler, and, as he hoped, a more easily manageable form that would render that theory more widely useful, besides extending its application to the measurement of some obscure quantities which had hitherto been considered rather elusive. He hoped to be able to point out some of those quantities, and the means of measuring them, at an early date.

In reply to Prof. Stroud, it only seemed necessary to point out that the apparent useful work of the fan was the product of the apparent ventilating pressure, and the apparent volume of air. These factors varied within wide limits according to the chosen places of measurement, and there seemed to be no general law, written or unwritten, to prevent a man choosing his places of measurement pretty much as he pleased. Hence miscellaneous experiments by different men on different fans might be made to furnish very unjust criteria of the relative excellencies or defects of the various machines.

Mr. M. Walton Brown moved a vote of thanks to Mr. Halbaum for his interesting paper on the graphic treatment of the theory of equivalent orifice, as applied to the ventilation of mines.

Mr. J. S. Martin (H.M. Inspector of Mines) seconded the resolution, which was cordially approved.

Mr. J. A. Jones's paper on "The Development and Working of Minerals in the Province of Leon, Spain," was read as follows:—

DEVELOPMENT AND WORKING OF MINERALS IN THE PROVINCE OF LEON, SPAIN.

By J. A. JONES.

Introduction.

The province of Leon is situated to the south of the province of Asturias. The division-line between the two provinces runs along the top of the Cantabrian range of mountains, which forms the westerly prolongation of the Pyrenees. This boundary begins at the Picos de Europa on the east, at an altitude of 7,785 feet, and ends on the west at a height of 6,463 feet above sea-level. It has on the east the provinces of Santander and Palencia; on the south those of Orense and Zamora; and on the west, that of Lugo.

The general course of its entire watershed is southerly, being drained by the affluents of the important rivers Miño and Duero, which flow through Portugal in their course to the ocean. All these affluents have their rise in the Cantabrian mountains, which as previously stated form the northern boundary of this province.

The topographical features of Leon are varied. Nearly one-third of its surface consists of flat plains, which formed the bed of a post-Tertiary sea. These plains, where irrigation has been established, produce abundant crops of wheat, barley, chick-pea (*garbanzos*), haricot beans and potatoes. Where there is no irrigation the ground is ploughed at intervals of eight to ten years, and in the intervals between, allowed to lie fallow. Wheat is then sown, and, if the weather be favourable, abundant harvests result, otherwise the crops are thin, and sometimes lost altogether.

Large quantities of potatoes, haricots and lentils are grown, forming the staple articles of food of the villagers, and an important branch of marketable produce.

These plains give grazing to immense flocks of sheep, and their wool supplies the cloth-mills of Cataluña. Flax is also grown in large quantities, part of which is spun and woven in hand-looms for family use, the surplus being sold in other provinces, where required.

In the district of Villafranca del Bierzo, a light and agreeable wine was formerly produced in large quantities, but some ten years ago the phylloxera infested the vineyards and destroyed them. This district is now recovering through the planting of the Californian vine, and a period of prosperity is again in sight. This district is also celebrated for its apricots, peaches, almonds, figs and walnuts.

Outside the plains, along the mountain-slopes, the crops consist of rye and potatoes, whilst the only fruit is the chestnut. These form the staple food of the villagers, and in bad seasons, with the failure of either crop, hunger is keenly felt.

The entire province has but little timber, and one may travel for miles without seeing a tree. Poplars grow along the margins of the rivers, and walnut, chestnut and oak-trees grow in the valleys amongst the mountains. As a higher altitude is attained, there are here and there small woods of oak. The lowlands left out of culture soon become overgrown by holm-oak (*quercus ilex*).

The climatic conditions are usually extreme. In summer, the temperature is high, averaging on the mountain-slopes 86° Fahr. in the shade, and on the plains 89° Fahr., while in winter it often goes down to 18° Fahr. on the lowlands.

Throughout the entire province, there is a defiance of all sanitary laws; and water, because of its abundance, appears to be the worst enemy of the people. The towns are bad enough, but the climax of filth is reached on penetrating to the villages among the mountains. There, the houses are built of dry stone, thatched with straw, without any regular form, and without window or chimney. The whole interior is one space, with a small portion on one side roughly partitioned off as the dwelling-place of the family and strangers, the remainder being devoted to cattle, sheep, goats, pigs and poultry, all roaming at will over the whole house. Manure is allowed to accumulate where it drops, and is only removed once a year.

The ways of communication are very deficient, especially about the mountain-slopes. All traffic is carried on the backs of mules. These are abundant and good, and every householder has one or more.

Despite the dirt and prevailing ignorance, the men make first-class workmen, are patient and enduring, and fit to work on a par with the best in the country.

Geological Features.

The geological features of the province are important. Several of the formations are well represented; others in wide gaps in succession are entirely absent. Up to the present, the work of the Geological Commission is not complete, and many alterations in their classification will yet have to be made.

The map (Fig. 1, Plate XIX.) is reproduced from that of the Geological Commission, augmented to a scale of 6·31 miles to 1 inch. Some alterations have been made in two districts after examination, namely:—In that of Busdongo, where Devonian is marked in the original map as Carboniferous (here the Old Red Sandstone, massive quartzite and red fossiliferous marble, abounding in fossils, are to be seen, the typical one being *Goniatites retrorsus*); and in that of Candin, on the west side of the province, where the division between the Lower Silurian and Upper Cambrian is marked by a bed of iron-stained conglomerate, 130 feet thick, which can be followed along the sierras, and forms a prominent feature of the same.

The fauna and flora of the Palæozoic is well represented, as may be noted from Table I., compiled from the work of many geologists.

The superficial area of the province is 6,762 square miles, and as the classification stands to-day is made up of the following formations:—

Ancient Acid Rocks...	6	square	miles.
Granites	13	,,	,,
Cambrian	260	,,	,,
Lower Silurian	2,243	,,	,,
Devonian	378	,,	,,
Lower Carboniferous	215	,,	,,
Upper Carboniferous	1,065	,,	,,
Cretaceous	61	,,	,,
Miocene	73	,,	,,
Quaternary	2,432	,,	,,
Alluvial	16	,,	,,

Mineral Wealth.

The mineral wealth is important, owing to the variety, and in some cases, abundance of mineral products, consisting of gold, arsenical pyrites, copper, nickel, cobalt, cinnabar, antimony, calamine, manganese, iron, coal and marble.

TABLE I.—PALÆOZOIC FAUNA AND FLORA OF THE PROVINCE OF LEON.

Name of Fossil.	Geological Horizon.	Places where found.	Recording Author.
Arionellus ceticephalus	Cambrian	North of Sabero	Verneuil and Barrande
Platyceras cantabricus	do.	do. do.	do. do.
Trochystites bohemicus ...	do.	do. do.	do. do.
Discina primæva	do.	do. do.	do. do.
Orthis primordialis	do.	do. do.	do. do.
Orthisina Pellico	do.	do. do.	do. do.
Conocephalites coronatus ...	do.	do. do.	do. do.
Paradoxides Pradoanus ...	do.	La Vecilla	Barrois and Verneuil
do. rotundatus ...	do.	Sabero	
do. bohemicus ...	do.	do.	
Cruziana Bronni	Lower Silurian	Maraña	Monreal
Monograptus Halli	Upper Silurian	Salas de la Rivera	do.
do. tenuis	do. do.	South of Villamanin	Mallada
do. convolutus ...	do. do.	Astorga...	Prado
Diplograptus palmeus	do. do.	do.	do.
Amplexus annulatus	Upper and Lower Devonian ...	Sabero	Verneuil
Zaphrentis gigantea	Lower Devonian	Pola de Gordón	Barrois
Chonetes minuta	Middle and Lower Devonian ...	do.	do.
Orthis fascicularis	Lower Devonian	Sabero	Vilanova
Strophomena rhomboidalis ...	do. do.	do.	Barrois
Leptæna Murchisoni	do. do.	do.	Verneuil
do. Maestreana	do. do.	do.	do.
Spirifer paradoxus	Middle and Lower Devonian ...	Sabero, Reinoso and Puerto de Cubillas ...	do.
do. Pallettei	Lower Devonian	Sabero	do.
do. cultrijugatus	Middle and Lower Devonian ...	Veneros and Sabero	do.
do. disjunctus	Upper, Middle & Lower Devonian	Sabero	do.
Athyris subconcentrica	Lower Devonian	Sabero and La Vecilla	Mallada
do. undata	do. do.	Sabero	do.
do. ferronensis	do. do.	Sabero and Puerto de Cubillas	Verneuil
do. Ezquerra	do. do.	La Robla	do.
Atrypa reticularis	do. do.	Puerto de Somiedo (divide between Leon and Asturias)	Mallada
Rhynchonella pila	do. do.	Orbó (north of Busdongo)	do.
do. Pareti	do. do.	Sabero	Verneuil

TABLE I.—*Continued.*

Name of Fossil.	Geological Horizon.	Places where found.	Recording Author.
Pentamerus galeatus	Lower Devonian	Pola de Gordón	Mallada
do. brevirostris... ...	Lower and Middle Devonian ...	Sabero	Verneuil
Terebratula Archiaci	Lower Devonian	Las Peñotas, Colle and Sabero	do.
do. Schulzii	do. do.	do. do. do.	do.
do. Bordiu	do. do.	Sabero and Colle	do.
Posidonomya Pargai	do. do.	Collado de Llama and Sabero	Verneuil and Barrois
Cardiola retrostriata	do. do.	do. do.	Barrois
Pleurotomaria subcarinata ...	do. do.	do. do.	do.
Platyceras priscus	do. do.	Sabero	Verneuil
Orthoceras regulare	do. do.	Collado de Llama	Barrois
Bactrites Schlotheimii	do. do.	do.	do.
Goniatites occultus	Upper and Lower Devonian ...	do.	Hinde
Bronteus Castroi	Lower Devonian	Colle	Mallada
Phacops latifrons	do. do.	Collado de Llama, Sabero, Trespando and Peña del Cuervo	Barrois and Verneuil
Dalmanites callitelles	do. do.	Colle, Sabero, Valcueva and Valdore ...	Verneuil
do. laciniata	do. do.	Orbó	Mallada
Homalonotus Pradoanus ...	do. do.	Colle	Verneuil
Equisetites giganteus	Middle Coal-measures	Puerto de Leitariegos	Areitio
Calamites Suckowi	Upper and Middle Coal-measures	Matallana, Ciñera and Sabero	Mallada and Ezquerra
do Cistii	do. do. do.	Orbó and Sabero	Ezquerra
do. approximatus ...	Middle Coal-measures	Puerto de Leitariegos	Areitio
do. cannæformis ..	Upper Coal-measures	Sabero and Ciñera	Areitio and Mallada
Calamocladus longifolius ...	Middle Coal-measures	Sabero	Ezquerra
do. equisetiformis ...	do. do.	Orbó (Busdongo) and Sabero	Mallada and Ezquerra
do. foliosus	do. do.	Cuenca de Rio Luna	Monreal
Sphenophyllum Schlotheimii ...	do. do.	Puerto de Leitariegos & Cuenca de Rio Luna	Areitio and Monreal
do. emarginatum ..	do. do.	Ciñera and Matallana	Mallada
do. erosum	do. do.	Orbó	Monreal
Annularia sphenophylloides ...	Upper and Middle Coal-measures	Ciñera and Orbó	Mallada
do. longifolia	do. do. do.	Las Babias, Brañuela and Orbó	Areitio
Sphenopteris Hœninghausi ...	Middle Coal-measures	Matallana	Mallada
Neuropteris gigantea	do. do.	Sabero, Orbó and Leitariegos	Ezquerra and Mallada
do. Loshii	do. do.	Orbó	Mallada

TABLE I.—*Continued.*

Name of Fossil.	Geological Horizon.	Places where found.	Recording Author.
Odontopteris oscendæformis ...	Upper Coal-measures	Puerto de Leitariegos	Areitio
do. Brardi	do. do.	do. do.	Mallada
Pecopteris arborescens	Base of Upper Coal-measures ...	Leitariegos, Ciñera, Matallana, Orzonaga, Sabero, Otero de Dueñas, Vegacervera, Orbó and Laceana	Ezquerra and Rubio
do. Miltoni	Upper and Middle Coal-measures	Otero de las Dueñas and Orbó	Areitio
do. polymorpha	Upper Coal-measures	Ciñera	Mallada
do. Plukeneti	do. do.	Matallana	do.
do. angustissima ...	Middle Coal-measures	Orbó	Areitio
Goniopteris arguta	Upper Coal-measures	Leitariegos	Mallada
Alethopteris lonchitica	Base of Middle Coal-measures...	Sabero and Matallana	do.
do. Serlii	do. do. do. ...	Las Bobias and Sabero	do.
do. aquilina	Upper Coal-measures	Ciñera and Orbó	do.
do. Grandini	do. do.	Orbó	do.
Dictyopteris neuropteroides ...	do. do.	do.	Areitio
do. Brongniarti ...	do. do.	Ciñera	Mallada
Lycopodium priniævum ..	do. do.	Puerto de Leitariegos	Areitio
Lepidodendron dichotomum ...	Upper and Middle Coal-measures	Orbó	Mallada
Halonia tortuosa	Middle Coal-measures	Ciñera	do.
Sigillaria tessellata	Middle and base of Upper Coal-measures	Matallana	Areitio
do. elliptica	do. do.	La Magdalena and Sabero	Areitio and Mallada
do. rugosa	Middle Coal-measures	Ciñera	Mallada
do. Cortei	do. do.	do.	do.
do. reniformis	do. do.	Orbó	do.
Stigmaria ficoides	Upper and Middle Coal-measures	Ciñera, Orzonaga and Matallana	do.
Productus Cora	Middle Coal-measures	Bobia	Barrois
do. semireticulatus ...	do. do.	Orbó	Mallada
do. punctatus	do. do.	do.	do.
Rhynchonella pleurodon ...	do. do.	do.	do.
do. flexistria	do. do.	do.	do.
Orthoceras giganteum	Carboniferous Limestone ..	Pola de Gordón	Barrois
Goniatites crenistria	do. do. ...	do. do.	do.
do. cyclolobus	do. do. ...	do. do.	do.

A short time ago, the Official Gazette announced some concessions of tungsten, but an error must have crept in, as the mineral is supposed to exist in the Upper Carboniferous, a most unlikely position for wolfram-deposits.

Gold.

Pliny and Sallust speak of the working of gold in this province and those of Asturias and Lusitania, and state that there was a yearly exportation of gold as tribute to Rome from these provinces of 20,000 pounds weight. An examination of their vast workings induces the belief that the assertion was not exaggerated.

The rivers Sil, Duerna and Eria have vast banks of gravel. The rivers Burbia, Ancares and Qua run through gorges until they join the river Sil. They all carry gold down yearly during the winter floods, and several of the villagers on their banks make it their business to pan during the summer months, getting daily in their rough way, gold to the value of 5 to 10 pesetas per head.

As already stated, there are very extensive beds of alluvium on the Sil and Duerna, and serious attempts have been made to work some of them. In 1887, the Rio Sil and Leon Mining Company, Limited, worked on the Duerna in one of these beds. They found it to consist of 180 feet of poor gravel overlying a rich layer that rested on the bed-rock. It was found that the Romans had already worked some of this layer in patches. The Roman method was to strip off the poor gravel-covering, by means of water-currents. The water was brought by aqueducts many miles in length to vast reservoirs made at a height above the gravel; when these were filled the sluice-gates were opened, and the rush of water carried off the barren deposit. The rich gravels were then sluiced. This system explains the patchy working.

This company sank several trial-pits to the bed-rock, at the foot of the gravel bluffs, with the following result:—

No. 1 Pit.—In a depth of 28 feet, the first 10 feet was a brown gravel with good prospects; the next 5 feet 9 inches, yellow gravel, sterile; and the last 12 feet 3 inches, rich gravel with coarse gold. Forty pans of this gravel on June 19th yielded an average value of 4s. 8d. per ton, and a further 20 pans on July 23rd averaged 2s. 9d. per ton.

No. 4 Pit.—The depth from the surface to pay-gravel was 10

feet 6 inches, and the same thickness of pay-gravel. The result obtained from 20 pans averaged 3s. per ton.

No. 5 Pit.—The depth to pay-dirt was 9 feet, and the thickness of pay-dirt was 7 feet. The average of 40 pans was 2s. 9d. per ton. Twenty tons of slimes when sluiced produced 2 dwts. 11 grains per ton. One nugget was obtained weighing 1 dwt. 2 grains, and another with crushed quartz-crystals weighed 33 dwts. 13 grains. The company ceased operations, owing to local difficulties.

The land along the river-sides is so subdivided as to proprietorship, that it would be a Titanic work for any company to treat with so many owners and buy up long continuous selvages of land. Moreover, as hydraulicking would soon raise the river-bed, and damage or destroy the land over a stretch of many miles, nothing could be done unless this is bought up. Then again the laws of the country prohibit the flow of débris into the rivers, and in hydraulicking on a large scale this cannot be avoided.

An attempt at hydraulicking this deposit some three years ago by a Spanish company brought disaster upon them. When the work was started, the farmers along the river-banks rose *en masse*, complained to the Provincial Governor, the workings were interdicted, and had to be suspended.

At Las Medulas, which flows into the Sil, in the Quaternary patch commencing at Ponferrada, the Romans worked on a very large scale, bringing the water for that purpose from a long distance. There are numerous remains of galleries and interior workings in an indurated clay-bound red conglomerate, holding from traces up to 3 or more dwts. of gold per ton. The red face of the almost vertical cliff on the western side, visible from a distance, has an altitude of over 150 feet. There is mention of this working in the ancient histories previously referred to, and in the surrounding district a whole category of folk-lore, all very interesting in its way.

At Paradaseca, there are other very extensive Roman workings in a bank of the same red conglomerate as that of Las Medulas. Pannings in this bed also give colours. This sheds into the river Burbia, whose gravels on panning yield the metal. The abrupt mountain-sides, and narrow bed of this river, with but few available patches of flat land along its bank for a distance

of 6¼ miles (10 kilometres), will permit the renewal of the working of these banks of conglomerate.

There are a number of other districts in the vicinity of the above-mentioned rivers that were worked on a very large scale by the ancients. Several of these deposits have been prospected by the writer, all containing gold, but most of them are unworkable nowadays, owing to the reasons previously referred to.

All the gold in these deposits is water-worn, consequently transported from elsewhere. Whence has it been derived? Prospecting was carried on up the courses of the rivers Sil and Ancares, with a view to tracing the origin of the gold to its source, and if possible to find whence the gravels and conglomerates had been charged. The prospecting shewed that the gold has been derived from the disintegration of the quartz-bodies and the ferruginous mica-schists which are met with along the river-beds, and about the head-waters up to the highest reaches of the dividing range.

The same formation extends northward, through Asturias to the sea, and in this latter province immense workings in the same rocks, all of ancient date, can be followed throughout.

Several quartz-reefs were discovered up the Sil, and tested with the limited means at hand. They are auriferous, and some are rich.

Special attention was given to the headwaters of the Ancares, and there the Menival mines were discovered—the only quartz-mines in work in the province. They are situated on a steep mountain adjoining the Ancares valley, in the district of Candin, affording every facility for working for a long time by means of open-cast and adit. The workings are 1½ miles distant from Candin village, where there is a spacious palace (the only available clean house for many miles around) which serves as a resting-place, after the ride of 18 miles (29 kilometres) from Villafranca. The altitude above sea-level at the upper workings in the mine is 4,800 feet, and at Candin 3,170 feet. The ore is found in the Upper Cambrian formation, and some characteristic fossils in the altered siliceous slate, awaiting classification, are found there.

The general country-rock is a ferruginous and grey slate, with regular beds of siliceous sandstone, here and there striated with

dark lines (specimens of this were exhibited), and reefs of irony quartz and quartz-conglomerate. On the top of the mountain, within the mine, there is a big blow of quartz, standing up above the surrounding surface to a height of 18 feet, 130 feet long by 36 feet wide, and in some parts it is highly ferruginous.

The ancients, probably earlier than the Phœnicians, sank a pit 40 feet deep in this, which when first discovered was partially choked with débris. This was cleared out, and disclosed very extensive workings. All these workings were cleared of débris resulting from falls, and a general sampling of the whole disclosed the fact that there was an average yield of about 8 dwts. of gold, while some samples of small veins in the body ran to several ounces per ton. The upper adit was then driven to intersect this mass at a depth of 60 feet below the sole of the old workings, cross-drives were put in, and a drive costeaning the mass, as shown in Fig. 2 (Plate XX.). These drivings went through irony quartz and large bunches of spongy iron, with abundant specks of visible gold. In the eastern drive, a 6 feet section of brown slate was crossed without any intermixture of quartz, giving 37 dwts. to the ton. A winze was put down, 20 feet, at the juncture of the quartz with the country-rock, and this also gave gold.

Seeing that the upper adit had successfully cut the ore, it was decided to start a second one at a depth of 556 feet lower. This has been driven 770 feet, at 682 feet it cut into auriferous ground continuing up to 765 feet. A cross-drive was put into the east at 682 feet, cutting through 7 feet of quartz intermixed with broken slate, all heavily charged with pyrites, and having some free gold. At 718 feet, another drive to the west has also cut ferruginous quartz with gold; and at 757 feet, a third drive to the west has also been carried on, intersecting several beds of quartz and auriferous matter.

The general sampling from these several cross-drives gave the results recorded in Table II.

In this adit, the quartz and gold-bearing rock was found to be different from the surface-blow.

Down the mountain-side are two large outcrops of quartz, which had not been sampled, but seeing that what had been cut in the lower adit-drives was a distinct reef or series of these, it was decided to examine these bluffs. At one spot, the ancients

had quarried in one of the bluffs, and after clearing it out, samples taken from the face give 10 dwts. per ton. Following the face of the quartz-bluff in a northerly direction for 395 feet (120 metres), other samples were taken which gave free gold in the pan of 10 dwts. per ton. This bluff where the last samples were taken has a vertical face, 26 feet, above the country débris (how much there is to bottom it remains to be seen), and a length in sight of 165 feet.

North-west of this bluff, at a distance of 700 feet, is another big bluff, having a vertical face of 130 feet, and a length of 160 feet. Samples from this gave pyrites, but no free gold in the pan.

TABLE II.

No. of Sample.	No. of Drive.	Silver per ton. Dwts.	Gold per ton Ozs. Dwts.	Total Silver and Gold. Ozs. Dwts.
210/1	682	3·3	0 11·0	0 14·3
210/2	,,	0·5	0 2·1	0 2·6
230/1	757	6·4	1 2·4	1 8·8
230/14	,,	2·1	0 7·1	0 9·2
230/15	,,	2·9	0 10·1	0 13·0
230/16	,,	1·2	0 2·1	0 3·3
230/36	,,	1·2	0 2·1	0 3·3
230/35	,,	3·8	0 13·2	0 17·0
G_1	718	5·8	1 1·0	1 6·8
G	,,	2·2	0 7·6	0 9·8
Average sample - -		3·0	0 10·2	0 13·2

The characteristics of these bluffs are identical with those of the upper quartz-blow, and it appears to underlie the whole contour of the mountains as a manto from crop to crop. Drives have now been started in both of these bluffs, and they will be thoroughly explored.

At the foot of the mountain, 2,800 feet (850 metres) from the upper adit, runs a river, which, with a leat of about 2,600 feet in length, can be utilized for milling with a head of 170 feet. Thus by a short automatic cable, the stuff can be taken to the mill, and it may be estimated that all costs will be covered by 4 dwts. per ton.

Within 3 miles, in the Burbia district, are extensive deposits of arsenical pyrites, all taken up as mines, but the owners have no capital to open them. Samples, on test, show gold. Here the ancients worked pretty extensively too. There are no roads to the place, only mule-tracks; the village is small, and as usual extremely dirty, although there is a river, which the people use for irrigating, but not for cleansing either their persons or their homes.

With the new regulations now in force as to payment of mining royalties, the titles of those existing here will in all probability be soon cancelled, through non-payment. Yet they are very promising. A tramway to Villafranca, following the river-side, could readily be laid for £8,500, the distance being about 14 miles (23 kilometres).

Copper, Nickel and Cobalt.

The various districts in the province where workable bodies of copper-ore have been found are Villamanin, Pontedo or Carmenes, Casares, Rjello, Oblanca, Boñar and Peñas Pintas in the Cordillera Cantabrica.

The Villamanin district has produced a large quantity of copper-ore. At about 2½ miles (4 kilometres) from the railway-station of this name, the celebrated Profunda mine is situated. It was discovered by accident in 1868. There existed some grown-over attle-dumps from ancient workings. An engineer, passing over the ground after heavy rains, which had produced a slip in these, noticed that they were speckled with green and blue carbonates, and had a black ore intermixed, which at the time was passed by as of no value. This black ore was rich cobalt oxide (asbolite). Efforts were made to discover whence these heaps proceeded, and the narrow entrance to an immense cave was discovered. On enlarging the entrance, it was seen that it was an ancient working. The walls were spotted throughout with copper, and inspection of the roof shewed that there remained a large quantity of ore to be worked. Steps were carelessly taken to stope this, resulting on the first attempt in the death of 5 men through the fall of a mass of solid black cobalt oxide, which had been left intact by the old workers, shewing thereby that they only worked for copper. Seven tons of ore were taken from the fallen mass.

Work was suspended for some time in consequence of this accident. When it was resumed, an adit was driven to tap the bottom of the cavern, which, during wet weather, filled with water. This adit cut some poor leaders of cobalt and copper carbonate, all crossing into the cavern. The débris was cleared out of this cavern, discovering a large number of stone hammers, and the entrance to some ancient galleries. These were explored, and found to be crusted over by hard condensed soot. Here and there

pieces of pinewood and pine-charcoal were found, shewing the great age of the workings, and climatic alterations since that date, because at the present day the province of Leon has not a single pine-forest. These galleries were all on the rise, and marks of fire were evident throughout. In breaking the crust formed on the floors of the galleries, more stone hammers and horn picks were found. The floor of the cavern was partly made up of fine débris, slimes from the crushed ore, carrying cobalt and a little copper carbonate: this shewed that under-stoping had been carried out.

The side of the mountain below the cavern is very steep (54 degrees); and a main adit was driven 147 feet vertical, lower down the slope, with a view to getting in below the cavern. It was driven by rule of thumb, for a length of 650 feet, and missed the ore. By chance it was noted that some distance back, in the portion of the adit that had been driven, there was a thin leaching of copper carbonate through a joint, or thin fissure, so a crosscut was put in, and at 10 feet (3 metres) struck the mass. This was driven through, and crosscut from wall to wall, proving it to be a chimney of solid ore, 72 feet long and 59 feet wide. An uprise to the cavern through 118 feet of ore, nearly half the distance understoped by the ancients, secured ventilation, and stoping in form was begun. This was carried out by opening stalls, and packing these with stone taken from the surface. At the same time, a winze was put down in it, and other adits were started, the lowest adit being driven at a depth of 229 feet below the main adit. The winzes went down in solid ore, to within a few feet of this level, where it was cut off by what is evidently a throw, as drives in all directions failed to strike the continuance. The whole of the mass above the lower drive has now been worked, and the mine is closed. Prior to its exhaustion, a pit was put down from the lower adit to a depth of 206 feet. This cut a big flow of water, which brought with it granular dolomite with grains of copper and cobalt intermixed, but the pumps were too weak to cope with it, the work was stopped, and thus it remains. There was a large dump of attle. Concentrating plant was erected, and the attle has been treated twice over, about 1,800 tons of normal percentage-ore being secured. The attle will stand another concentration yet, with good results.

When the mass was struck, the first ore cut was a gouge of

solid cobalt oxide, about 6 inches thick, then solid ore, which was separated, when drawn, into three classes, giving the following percentages:—

Classes.	Cobalt. Per Cent.	Copper. Per Cent.
No. 1	2·05	36·0
No. 2	6·40	35·7
No. 3	17·20	27·0

That part of the chute which was above the main adit gave these averages; but thence downward the cobalt gradually worked down to a little over 1 per cent. on an average, and the copper settled into a regular ore varying between 29 and 31 per cent., until the whole was exhausted. The upper ore was for the most part a mixture of carbonate and oxide; as a greater depth was reached, sulphide predominated.

The mine is situated in the Upper Carboniferous formation. A section across the strata is shewn in Fig. 3 (Plate XX.). The ore-carrier is a crystalline dolomite (*rauchwacke*) whose surface reef-like croppings can be followed over a run of 7 miles in an east-and-west direction. Here and there, it shews carbonate of copper and specks of cobalt, but up to the present time there has been no such strike as that of the Profunda mine in any other section, although small parcels of ore, both copper and cobalt, have been drawn from it by people who had the mining fever after the Profunda find, but did not possess the necessary capital to prosecute the work. There is no gypsum in the vicinity, consequently the mode of formation of these dolomite-beds is as yet a secret. The immense body of fetid limestone in which the dolomite occurs has yielded from its worn surface beautiful branch-like specimens of red metallic copper, which on breaking shewed radiations from a central point, probably formed by the metamorphism of encrinites existing in the limestone.

There is no reliable information as to the quantity worked, but as all the ore has been shipped through Asturian ports the statistics obtainable shew that this reached in round numbers 28,000 tons. The cost of the ore per ton at Swansea, all included, has averaged £2 13s.

In the Pontedo (Carmenes) district is a separate run of dolomite from that of the Profunda mine. It lies farther north, but it is quite as massive.

The position of the Providencia mine may be noted on referring to the plan of the group, Fig. 4 (Plate XX.). A plan and section of the workings is shewn in Figs. 5 and 6 (Plate XX.). The discovery of this mine resulted from an accident. In 1878, a shepherd found that one of his flock had tumbled through a hole into a cave. He went after it, and saw that he was in a big place. He spread the news, and a miner who, some days afterwards, reached the village, heard of the discovery. He examined it, went at once to the government office in Leon, and registered it.

The working marked "cueva" was due to the old workers. They commenced their work in an extensive iron gossan with malachite-crystals interspersed in it. Here, the usual stone hammers remained as a proof of the antiquity of the excavation. Its walls and roof shewed the class of ore which they extracted, and a portion of the floor was in solid ore. A main adit and drives were made on that level, and a connexion was made from the cueva to this level in the ore-mass. The average assay of this ore was:—Copper, 8·47 per cent.; cobalt, 2·68 per cent.; nickel, 6·43 per cent., with a lime and magnesia carbonate gangue.

The ore was nipped out a little above the lower adit, by a fault. The galleries marked in Figs. 5 and 6 (Plate XX.) cut a small body of ore giving an average assay of:—Copper, 5·19 per cent.; cobalt, 2·93 per cent.; and nickel, 5·28 per cent. Sinking and driving was continued from the bottom of No. 2 pit but failed to meet with any important body of ore.

The No. 3 pit came upon the ore-mass at a depth of 16 feet, and was carried down a further 56 feet in solid ore, this continuing in the sump. Then cross-drives were put in from the bottom for a length of 88 feet east and west and 26 feet north and south, only meeting the western and southern walls. Excavation was carried on, forming a vast chamber, 10 feet high, leaving solid ore over roof, floor and walls on two sides. Communication with the No. 2 pit was made by an uprise, to permit the placing of a winding-engine and pumps to draw and deliver on the lower adit, and do away with the hand-winches and pumps that had been employed up to this time. Then the work was suspended.

General sampling of the mass was carried out systematically, and a parted sample, assayed by Mr. F. Claudet, gave the following result:—Copper, 14·50 per cent.; nickel, 7·28 per cent.; cobalt, 3·15 per cent.; iron, 3·28 per cent.; sulphur, 27·00 per

cent.; carbonate of lime, 21·89 per cent.; carbonate of magnesia, 17·59 per cent.; siliceous rock, 5·10 per cent.; and oxygen and loss 0·21 per cent.

The ore was shipped to Swansea. Difficulties arose respecting its sale, owing to the presence of the three metals, intimately combined. The metals in the ore are all in the state of sulphides, and it may be classed as Linnæite. This refers to the ore-mass cut in No. 3 pit, but in the upper workings the ore was chiefly oxides. In view of the sacrifice in value on its sale owing to the difficulty of obtaining payment for the three metals, experiments on an important scale were carried out at Battersea by Mr. W. Blenkinsop, with a view to the separation of the metals by a wet method of his own invention. This he did most successfully, and a contract for the erection of works on the mine was discussed, but it fell through.

The working about the cueva in the Providencia mine yielded the following assays:—

No. of Sample.	Analyst.	Cobalt. Per cent.	Copper. Per cent.	Nickel. Per cent.	Manganese. Per cent.
1.	Mr. Danois.	5·20	11·70	—	—
2.	School of Mines, Paris.	6·60	15·80	6·71	—
3.	Do.	48·26	—	5·11	—
4.	Mr. Danois.	30·15	10·60	—	—
5.	Mr. Weil.	21·45	5·75	—	4·85
6.	Mr. Guignet.	34·97	—	—	—

The Rezagada mine was also partially opened, and some good ore was found. A parted sample, assayed by Mr. Frederic Weil, contained:—Copper oxide, 34·2 per cent.; cobalt oxide, 5·2 per cent.; iron oxide, 5·463 per cent.; iron sulphide, 1·106 per cent.; lime, 8 per cent.; magnesia, 4·4 per cent.; arsenic acid, 11·241 per cent.; silica, 1·7 per cent.; carbonic acid, 28·59 per cent.; and loss, 0·1 per cent.

Another sample, assayed by Mr. Leon Ridult, gave:—Silica, 2·8 per cent.; iron, 18·25 per cent.; copper, 35·6 per cent.; sulphur, 27 per cent.; and volatile matter, 16·35 per cent.

Another sample, assayed by Mr. Billaut, gave:—Silica, 0·3 per cent.; iron peroxide, 5·3 per cent.; manganese oxide, 0·3 per cent.; cobalt oxide, 51 per cent.; and nickel, 12 per cent.

When the writer examined the Rezagada mine in 1894, the workings had collapsed.

Some mines were taken up at Oblanca, on the left bank of the river Luna, at a height of 1,640 feet above the valley. Here are strong masses of dolomite, with abundant signs of copper. An open cut was made, following an outcrop of copper-ore, and in this a shaft was put down 60 feet, following the vein down. Out of this work, 3 tons of picked ore were saved, yielding on assay:—Silica, 2·8 per cent.; iron, 18·25 per cent.; copper, 35·6 per cent.; and sulphur, 27 per cent. Some drives were put in from the bottom of the shaft, and the vein continues in the ends. At 230 feet above this work, another outcrop of promising ore exists. A trial-gallery was put in, shewing that it was worthy of further exploration, but this was left undone, and the whole thing remains to-day as it was left in 1885.

In the Boñar district are some outcrops of pyrites assaying 24·74 per cent. of copper. They are found in the Cretaceous, in the form of a reticulated bed of stringers, enclosing loose sand. The encasing walls of ore of this network vary in thickness from ½ inch to 1½ inches. A mining sett exists on this, but a pick has not been put into it.

The Casares mine lies west of the Villamanin railway-station, and distant 4 miles from it. It is in the same run of dolomite as the Profunda mine. A short gallery was driven, where there was a small show of copper carbonate in the dolomite-face. The gallery cut through a vein of solid ore, composed of carbonate and oxide of copper, 18 inches thick, and was continued for some feet farther, to see whether a big mass would be cut, but this was not found. No further work has been done since 1892 to the present time.

Peñas Pintas mine is situated in the Carboniferous formation of the district of Valderueda. Here some large moved blocks of grey copper, assaying 72 per cent. of copper, were found in 1880. A good deal of exploratory work has been done, but the origin of the blocks has not been discovered. The sett has now been retaken, and further explorations promise better results.

Working has been proceeding at Riello for some years, opening up about 334 acres of argentiferous copper-mines, in which extensive preparatory work has been carried out. A complete con-

centrating plant is being installed, with six Wilfley tables, and the mine will be shortly in a position to begin shipping rich concentrated ore. This will be carted 25 miles to the Leon railway-station over a good road, and forwarded by rail to a shipping port.

Antimony.

Some 37 years ago, antimony-ore was found in pockets in Carboniferous Limestone at Maraña, and about 200 tons of clean sulphide was extracted; but the pockets gave out, and difficulties with the workmen, and the want of roads caused the abandonment of the mine.

A large deposit of antimony-ore, intermixed in a limestone-gangue, was opened out in the Riaño district, some years ago. It could not be spalled down so as to increase the percentage by hand-picking, owing to the intimate intermixture with the gangue, and this mine also is shut down.

Cinnabar.

Surface-indications of cinnabar were discovered in 1875 in Carboniferous sandstones of Valdesamario, and mining-setts were secured. Some work was done, consisting of a shaft 60 feet deep, with lateral drives from the bottom. The object of these was to see whether the percentage would increase. The ore continued downward, and here and there small nodes were found assaying 32 per cent. of mercury, but the average did not reach 1 per cent.

Zinc.

On the southern slopes of the Picos de Europa, within this province, are extensive masses of clean white and grey carbonates of zinc, filling large cavities and breaks in Carboniferous Limestone, but there is no road or other ways of transport within reach, and although there are several mines secured, these must remain inactive until the country has been opened up by roads or railways.

Near Friera, 2½ miles (4·5 kilometres) to the west of Toral railway-station, in the Cambrian formation, there is a bed of crystalline limestone, 490 feet thick. Near this, a vein of good calamine has been worked for a number of years, extracting a relatively large tonnage. It was a contact-vein, nearly vertical, having a

thickness varying from 1 foot 8 inches to 4 feet. It at length became unpayable through pinching, and last year the mine was abandoned.

Two miles (3·5 kilometres) farther west, at Sobrado, is another bed of the crystalline limestone about 1,500 feet thick. In this mass, near the top of the mountain on the southern side of the river, are some very extensive caves, formed by the passage of a subterranean river: this is shown by the water-worn walls. The first large cave, having a height of 80 feet, has its walls beautifully tapestried by delicate curtain-like stalactites, these also hanging down from the roof in fine array, while the massive stalagmitic fountainlike forms on the floor, and here and there noble columns, give the appearance of an enchanted palace. The trace of copper sulphate in the calcspar gives to the whole a lovely coloration. These caves have not been explored up to the present, as both ropes and ladders are needed for this purpose. The distance by road from the Toral railway-station to the caves is about 5 miles (8 kilometres).

Manganese.

Several mining-setts have been taken up in the province, but up to the present time work has not been commenced. The heavy freight to a shipping port from most of them will be a bar to successful working.

One of these, situated in the Boñar district, was examined by the writer a few days ago. All that could be seen were the surface-croppings in Devonian sandstone, with a lode of manganese and manganiferous iron. The first, where examined, had a thickness of 1 foot 10 inches (of good pyrolusite), and the second of 3 feet 6 inches.

Iron.

The province has abundant beds of iron-ore. Difficulties of transport have been the cause of inertia in the working of these, together with distance from seaports and high railway-tariffs.

The three beds of Devonian iron-ore, described in a former paper,* exist here under similar conditions, but with increased strength. They run westward throughout the Devonian forma-

* *Trans. Inst. M.E.*, vol. xviii., pages 279 to 292.

tion, with three series of outcrops. The northernmost, beginning at Busdongo, can be followed westward throughout the formation. Two of these beds are 10 feet thick, and the middle one 7 feet, with a heavy dip (70 degrees). The ore is coarse-grained, with such fossils as *Pecten*, and includes very small rounded pebbles of an older iron-ore. It assays:—42·68 per cent of iron; 0·98 per cent. of phosphorus; and 23 per cent. of silica.

The second series of outcrops are followed from below Villamanin to Lanjaron, nearly parallel with the former. The ore was partly worked, many years ago, near Villamanin by open-cast, for the Mieres iron-works. It has about the same percentages as those given above, but there is a far greater abundance of fossils, whose calcareous shells have been replaced by iron.

Following south to Barrios de Luna, the third series is found, these continue westward throughout the formation, and eastward up to the Carboniferous, passing under this, and emerging once more to the surface as soon as this has been passed, following in the Devonian eastward to beyond Boñar, where they were examined by the writer on August 6th and 7th of the present year.

The whole of these deposits have now been taken up as mines, but work has not yet been commenced in them.

The first series from Busdongo crops out over a run of 9 miles (15 kilometres). The second or Villamanin series runs over 12½ miles (20 kilometres); and the third or Barrios de Luna series, east-and-west, can be followed for 27½ miles (45 kilometres). There are many millions of tons of this ore to be worked above water-level.

There are some extensive deposits of hæmatite, averaging between 59 and 62 per cent. of iron, in the Carboniferous rocks near the village of Villafeliz. Some extensive deposits of similar ore have been discovered in the districts of Brañuelas and Bembibre: these occur at some distance from the railway, and the writer has so far found no time to examine them.

The *furore* that has arisen for iron-mines has induced the registration of these, wherever there is any indication of ore, without enquiry into the economic conditions; and there are many so-called mines which will never be of the slightest value, because the ore in them is simply a big sample. Others are inaccessible to road or rail, and even the best among them will

allow only of a meagre profit, owing to the long and costly railway-carriage to port. They may be worked to supply local smelting-works, which could be established in several places, as coke can be obtained from the provincial collieries and those of Asturias; there would be no lack of limestone or water; and wages are low. Thus the manufacture of common pig-iron and its transport to market could be carried forward under economic conditions advantageous to the smelters.

This was attempted from 1860 to 1870 at Sabero: a blast-furnace, forges and mills were erected, and worked for some time, using these siliceous ores, smelting with coke produced at collieries in that neighbourhood. At the time there were no railways in the province of Leon, and consequently all the produce had to be transported by cart. So when this iron got into the limited market that it could reach, it could not compete with that of the numerous Catalan forges spread over the western portion of the province, hence it was closed. (Some of these forges still survive.)

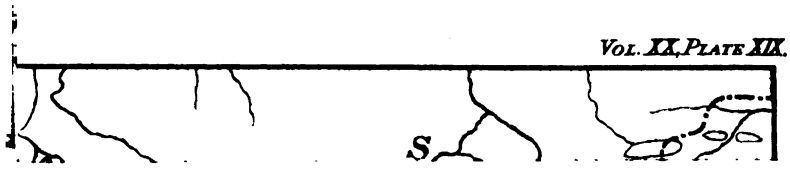
To-day there is some talk of again reviving the smelting in Sabero with improved furnaces and modern plant, and the project may now succeed, as there are railway-facilities, the cost of all raw material will be low, and labour cheap.

Coal.

Coal promises to become an important branch of mining in the province, in view of the extent of its coal-fields. It is now being developed on a gradually increasing scale.

The railway from La Robla to Bilbao passes within reach of one series of coal-fields, which have good seams of coal. Matallana, Sabero and Valderrueda are opened by this railway. The workable seams here vary in thickness from 18 inches to 8 and more feet, they are heavily pitched, and worked by gallery and modified longwall. The coal from this coal-field is for the most part good coking, and, up to the present time, what is made in the locality is coked in mounds.

The Santa Lucia coal-field in the Pola de Gordon district is served by the Northern of Spain railway. Some of the seams here are anthracitic, and others semi-bituminous. There is a modern washing-plant and a briquette-works on the principal mine. The production is sold in the country.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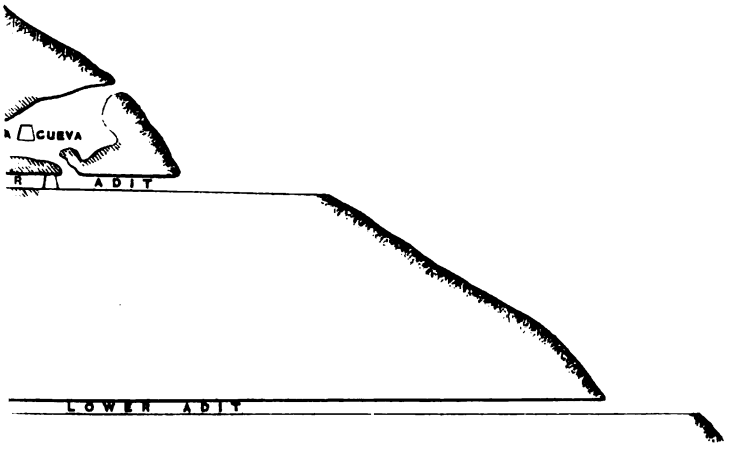
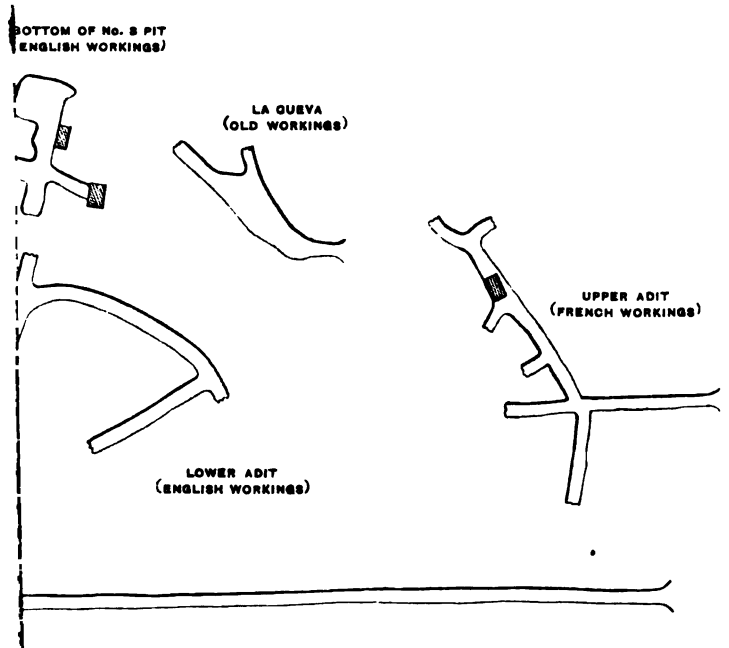


FIG. 6.—SECTION OF WORKINGS OF PROVIDENCIA MINE.

Scale, 1,050 Feet to 1 Inch.



AN OF WORKINGS OF PROVIDENCIA MINE.

There are three other districts worked on a small scale to supply local requirements in the case of two of these, whilst the third has not been touched. These are Cuenca de Rio Luna, Valdesamario and Fabero. These are situated far from a railway.

The Fabero district is a very important one, owing to the strength and regularity of its seams of good coking coal, but up to the present time these have not been touched owing to the absence of transport-facilities.

The official statistics of the production of coal in the province for the quarter ending June 30th, 1900, as compared with that of the same quarter of 1899, is as follows:—

District.	1899. Quarter ending June 30th.	1900. Quarter ending June 30th.
	Tons.	Tons.
Pola de Gordon ...	7,795·95	18,055
Sabero	5,768·00	11,382
Matallana	12,887·00	6,090
Valderrueda	312·00	3,785
Cuenca de Rio Luna ...	140·90	505
Valdesamario	—	6
Totals	26,903·85	39,823·

Mr. A. Watters (Liverpool) wrote that the quartz outcrops of the Candin district are extensive and phenomenal in their auriferous character, as shewn by frequent samplings, pan-tests and chemical assays. One of these masses of quartz crops out to a height of 130 feet, and although samples taken from the exposed face only yielded pyrites in the pan as stated by Mr. Jones, after penetrating beyond the weathered portion, subsequent samples yielded results which might safely be computed at 2 ounces of gold per ton of ore.

The Chairman (Mr. H. C. Peake) moved a vote of thanks to Mr. Jones for his interesting paper.

Mr. John Gerrard (H.M. Inspector of Mines) seconded the motion, which was cordially approved.

Mr. James Stirling's paper on "The Geological Ages of the Gold-deposits of Victoria" was read as follows:—

THE GEOLOGICAL AGES OF THE GOLD-DEPOSITS OF VICTORIA.

By JAMES STIRLING, Government Geologist of Victoria.

Introduction.

The value of the gold already won from Australia is about £416,000,000. The colony of Victoria, although occupying only 3 per cent. of the total area of the Australian continent, has produced £259,120,396, or more than one-half of the total; in fact Victoria is, next to California, the greatest gold-producer in the world (during the last 50 years, or since 1850). The following table will show this:—

	£
California	280,000,000
Victoria	259,120,396
Russia	252,000,000
Brazil	180,000,000
Witwatersrand	64,000,000

In order to present clearly the conclusions respecting the age of the formations in which gold has been found, the writer will briefly refer to the sequence of the rock-masses which constitute the geological record in Victoria. Gold-production has certainly been an important factor in promoting settlement, and in the development of industries.

Cambrian.

The oldest sedimentary rocks at present known are certain shales near Heathcote, in which fossils of a Cambrian facies have been found namely, a trilobite, *Dinesus Ida*; and a brachiopod, *Lakhamia linguloides*.

It is not improbable that some of the highly metamorphosed Palæozoic rocks of the Australian Alps may, upon close investigation, prove to be representatives of this formation.

Silurian.

The principal sedimentary Palæozoic rocks covering an area of 28,300 square miles are undoubtedly Lower and Upper Silurian or their metamorphosed representatives, some of the phyllites and mica-schists described elsewhere as the regional crystalline schists.

Lower Silurian.

The Lower Silurian consists mainly of slates, indurated shales and sandstones of the principal gold-fields, with which are interbedded dark and variously coloured carbonaceous slates containing impressions of graptolites of the following genera: *Bryograptus, Climacograptus, Clonograptus, Dendrograptus, Dichograptus, Dicellograptus, Dicranograptus, Dictyonema, Didymograptus, Diplograptus, Gladiolites, Glossograptus, Goniograptus, Lasiograptus, Leptograptus, Loganograptus, Phyllograptus, Retiolites, Stephanograptus, Temnograptus, Tetragraptus* and *Thannograptus*. There are also several *Protospongia* and, among the Crustacea, a *Lingulocaris*.

The beds have been acutely folded, and consequently present high angles of dip. They are intruded by various eruptive rocks of the granitic, porphyritic, felsitic and basaltic classes; and are intersected over large areas by veins of quartz, mostly auriferous. The intrusion of the granites has not only caused a considerable amount of contact-metamorphism, converting the slates and sandstones into varieties of hornfels rock, nodular schists or quartzite where the action has been greatest; but has also, in some areas of regional metamorphism, completely absorbed the sediments.

Upper Silurian.

The Upper Silurian beds are less completely folded than the Lower, and consist chiefly of shales, sandstones, mudstones, conglomerates and limestones. They are also in places affected both by regional and contact metamorphism. They are intersected by numerous dykes of porphyry, felsite, diorite and aphanite. The limestones and calcareous sandstones have yielded an abundant fossil fauna of the following genera: *Monograptus* and *Tetragraptus*; *Cladophora, Coenites, Cyathophyllum, Cystiphyllum, Diphyphyllum, Favosites, Heterotypa, Plasmopora, Pleurodictyum, Rhizophyllum, Trematopora* and *Tryplasma*; *Alveolites,*

Fenestella, *Heliolites*, *Monotrypa*, *Palaeopora*, *Petraia* and *Stromatopora*; *Bronteus*, *Calymene*, *Cheirus*, *Forbesia*, *Homalonatus*, *Lichas* and *Phacops*; *Atrypa*, *Leptaena*, *Neuclospira*, *Orthis*, *Pentamerus*, *Rhynchonella*, *Spirifera*, *Spirigerina*, *Strophomena* and *Trematospira*; *Bellerophon*, *Cyclonema*, *Eionema*, *Euomphalus*, *Murchisonia*, *Naticopsis*, *Niso*, *Phanerotrema*, *Sphenotus*, *Stomatia*, *Tremanotus*, *Trochus* and *Tryblidium*; *Ambonychia*, *Cardium*, *Grammysia*, *Orthonota*, *Pleurorhynhcus* and *Pterinea*; *Desioceras* and *Orthoceras*.

It is noteworthy that the diorite-dykes of the Upper Silurian areas are invariably accompanied by quartz-veins either intersecting them or near them.

Devonian.

The Devonian beds are divided into Lower, Middle and Upper.

Lower Devonian.

With the exception of certain beds of calcareous sandstone near Healesville, and some sedimentary rocks in the valley of the Thompson, which contain fossils of a possibly older Devonian facies, all the rocks hitherto recognized as of this age are of plutonic and igneous origin, consisting of granites, granitites, quartz-mica-diorites, pegmatites, aplite, porphyries, porphyrites, banded porphyries, felsites, etc., representing the wreckage of old volcanic outbursts, ejectamenta now forming consolidated and silicified tufas, ash-beds and agglomerates (the cores of such volcanoes together with other masses of eruptic rocks and their apophyses), which have probably cooled under the pressure of great superincumbent masses and have since been exposed at the surface by long-continued denudation. The Cobberas mountains belong to the former, and most of the granitic masses and dykes to the latter, class. It is held that the greater part of the quartz-veins traversing the Silurian rocks—whether such occur as contact-lodes (*i.e.*, lodes formed at or near the contact with the eruptive rocks), in fissures in the unaltered Silurian sediment, or intersecting and associated with the dykes—were formed either during or towards the close of this period of intense volcanic activity. It has been shown that there is a relation between the metamorphism of the sedimentary rocks and the period of the formation of numerous auriferous lodes over large areas of the Australian Alps.

Mr. A. W. Howitt, has, by his petrographic work, shown the connection that undoubtedly exists between the eruptive rocks of post-Silurian age and the origin of numerous auriferous lodes in Victoria. Having traversed the areas referred to in Mr. Howitt's writings, the writer can vouch for the research which such petrographical investigations display in their bearing upon the geological age of a very large number of the auriferous deposits of Victoria. It was first shown by Mr. Howitt's investigation of the Devonian rocks of North Gippsland "that many areas were covered by rocks which were formed from volcanic ejecta, and others as plugs of volcanoes, or injected erupted masses formed during the intervening period between the close of the Silurian period and the middle of the Devonian."

The following descriptions will shew that there is an abundance of evidence that the auriferous quartz-veins over the greater part of Victoria are clearly post-Silurian and pre-Triassic in point of age. At the same time, while there is undoubted evidence of the formation of quartz-veins during Tertiary times, there is no proof that any of the auriferous veins now being worked are of Tertiary age, and this is all the more remarkable as geological investigations, now being carried out by the Geological Survey of Victoria, shew that during Tertiary times there was not only an extraordinary outburst of volcanic activity, but that extensive silicification of the sediments took place.

Some of the localities shewing the effects of the invasion of plutonic magmas during Devonian times will now be described.

Swifts Creek.—In the watershed of Swifts creek, in the Tambo valley, there is an area of metamorphic and plutonic rocks. The plutonic rocks, which have here invaded the sediments, presumably of Silurian age, if not older, were found to be mainly diorites in which the felspars were of various composition, between oligoclase on the one hand and anorthite on the other. The sedimentary beds have been greatly disturbed and much metamorphosed, in places to hornfels, and in other parts to nodular mica-schist. The plutonic rocks comprised granite, quartz-diorite, aplite, quartz-porphyrite, and in one instance amphibole-picrite. The auriferous lode-formations were found to be connected with the contact-action of the intrusive plutonic rock.* Again, certain

* "The Diorites and Granites of Swifts Creek, etc," *Transactions of the Royal Society of Victoria*, 1880, vol. xvi., page 11.

dykes of quartz-porphyrite and syenite-porphyry found at or near the contact of a large intrusive mass of quartz-diorite with the sedimentary formation, which cannot be younger than Middle Devonian, proved to be associated with contact-lodes containing gold.*

Dargo.—In the Dargo valley, at Dargo, there is an area of quartz-diorites, which have intruded into the Lower Silurian sediments, and has produced a strongly marked zone of contact-schists of the hornfels type. The mica-schists and gneiss so characteristic of the metamorphosed area of the Omeo district were also observed in this area. The intrusion has been accompanied by numerous dykes comprising aplites and porphyries; and, as in other instances of diorites, which have been intruded into the Silurian sediment, auriferous contact-lodes have been generated. These have been worked at Dargo with profitable results. The hornfels agrees in all essential respects, not only with similar formations in Victoria, as for instance with those at Beechworth and Maldon; but also with those occurring elsewhere, for instance in Germany, as described by Prof. Rosenbusch in his work on the "Steigerschiefer."†

Noyang.—At Noyang, in the Tambo valley, there is a great mass of intrusive rocks of which Mount Elizabeth is the culminating point. It comprises quartz, mica, diorite, keratophyre, quartz-mica-porphyrite, granophyre, quartz-porphyrite, felsophyre, diorite and diabase. The larger and older masses have been penetrated by the porphyritic members of the group, and finally by numerous dykes, the whole being surrounded by a mantle of contact-schists—on the south-eastern side of hornfels, and on the northern side of mica-schists. The period during which these igneous masses were intruded was between the close of the Silurian and the commencement of the Upper Devonian period. A few miles to the west occur the auriferous quartz-veins of the Haunted Stream gold-field.‡

* "Notes on the Microscopical Structure of some Igneous Dykes of North Gippsland," *Journal of the Microscopical Society of Victoria*, 1881.

† *Transactions of the Royal Society of Victoria*, 1887, vol. xxiii., page 135.

‡ *Ibid.*, 1884, vol. xx., page 18.

Ensay.—A few miles north of Noyang, at Ensay, are crystalline schists associated on the one hand with sedimentary rock, on the other with quartz-diorites. The Lower Palæozoic sediments in this locality have been intruded by plutonic magmas and these have altered the sediments into mica-schists, while in the same locality gneissose beds have resulted from the metamorphism of granitic rocks.

Omeo.—Immediately north of Omeo, in the Livingstone creek valley, some miles distant from the Swifts creek area previously referred to, the sedimentary beds have been metamorphosed into nodular-schist and mica-schist, while another class of mica-schists and gneiss has been produced by dynamometamorphic action on granites and quartz-diorites. Certain aplites and orthophyres, as well as large dyke-like masses of syenitic porphyry were unaffected by metamorphic action. Some time ago, the writer examined microscopically the metamorphic and plutonic rocks of the Livingstone creek and Dry gully auriferous areas, and found that various dykes represented distinct periods of eruption since Palæozoic times; the more recent felsitic dykes were accompanied by milky white quartz-seams of a non-auriferous character, whereas the veins of quartz associated with the older diorite-dykes were distinctly auriferous.

Upper Dargo.—It was for a long time believed that the transition from unaltered Silurian sediments through mica-schists and gneiss into massive rocks of a granitic character could be seen in the Australian Alps. The critical examination of the rocks in the Upper Dargo river, where such transition was supposed to occur, disclosed the fact that there were two groups of schistose rocks, the one being mica-schist (the actual metamorphosed representative of the Silurian sediments) the other being mica-schist and gneiss, metamorphosed plutonic rocks of either the quartz-diorite or granitic class.* Numerous auriferous quartz-veins have been discovered along the zone of altered Silurian rocks.

Heathcote.—Doubts having arisen as to the geological age of some of the formations surveyed by the Geological Survey, near

* "Notes on the Contact of the Metamorphic and Sedimentary Formations at the Upper Dargo River," by Mr. A. W. Howitt, *Special Reports of the Department of Mines, Victoria*, 1892, page 9.

Heathcote, it was decided to examine them microscopically, and it was found that the Cambrian and the Lower and Upper Silurian sediments had been intruded into by large masses of unusually porphyritic-diabase and diabase-porphyries, the sediments of contact having been altered to rock analagous to adinole, the extreme form being lydianstone. Subsequently the diabase-formation suffered intrusion by granite of an aplitic character. When the intrusion took place, the diabase had been altered by the breaking up of the augite into forms of amphibole, finally resulting in rocks almost wholly composed of actinolite. The rhombic pyroxene is represented by enstatite, which has also disappeared in this process. The auriferous lodes were formed in connection with the granitic and not with the diabase-intrusions.

Dykes.—Three localities are now being petrographically examined by the writer in connection with geological and underground surveys in progress, by the officers of the Victorian Geological Survey, including the mining district of Walhalla, Tanjil and Woods Point; and also the features of the altered rocks and dykes at Stawell and Maldon. Some general features of the mining geology of these areas can only be briefly referred to in this paper.

Walhalla.—At the Long Tunnel mine, the dyke trends slightly west of north, parallel with the Silurian strata, and it is impregnated more or less with iron and arsenical pyrites. Two quartz-lodes meeting in an apex or cap accompany the dyke along or near to and within its walls on either side, while others intersect the body of the dyke. The shoots of auriferous quartz dip northward, the underlie being westerly. The Long Tunnel mine is a splendid instance of the permanence of auriferous veins associated with dykes. The shaft at the end of 1899 was sunk to a depth of 2,220 feet. The whole of the belt of country extending northward from Walhalla, through the heads of the Jordan and over the Dividing Range at Matlock to Woods Point, and still farther northward to Jamieson, is auriferous and of similar character; although on the Dividing Range, near Matlock, there is probably a junction of the Lower and Upper Silurian beds, from the occurrence of fossil graptolites found there by the writer's colleague, Mr. Ferguson, 300 feet or more below the saddles.

Tanjil.—At this locality, situated south west of the Walhalla belt, numerous dykes occur: the relation of these to the enclosing strata and their mode of occurrence has been clearly described by the writer's colleague, Mr. Hy. Herman, in an official report on "Mining at Tanjil," as follows:—

> The Silurian strata, which strike about north-north-west, consist of highly-inclined thickly-bedded mudstones, slates, shales and sandstones, the first-named predominating in the immediate neighbourhood of Tanjil. Traversing these beds in the direction of their strike are numerous quartz-reefs, many of them well-defined bodies of stone, traceable for many chains. Cutting across the strike of the Silurian rocks, and intersecting the quartz-reefs at an angle of about 45 degrees, are numerous parallel dykes. These strike, with remarkable regularity, about 25 degrees north of west, thus forming with the reefs a rhomboidal network; underlie nearly vertically but generally a little to the south, and can also, like the reefs, be traced for considerable distances. Innumerable thin quartz-veins, from a streak to a couple of inches thick, and on an average 9 to 12 inches apart, run through the dykes from wall to wall in a north-and-south direction. These veins underlie west-north-west (in direction of strikes of dykes) at about 20 degrees very regularly, and enter the walls on either side for a short distance only. The walls are true and well defined, generally of hard mudstone, and along them in many places runs another system of quartz-veins which, with the set described above, appear to occupy the fissures formed in the dyke-material owing to contraction while cooling. The dykes vary a good deal in thickness, thinning out in places to a few inches, and then suddenly widening out again to several feet. This thinning-out is probably due to faulting along the line of fissure, and need cause little doubt as to the continuation of the dyke. Wherever this feature is met with, the track of the dyke should be driven on and another "make" is almost sure to be struck. The dyke-material near the surface is decomposed to a soft soapy clay, but gradually hardens in depth to a hard, tough, hornblendic rock, and the development of large cubes (up to ¼ inch) of iron-pyrites in the dykes and the adjacent country-rock is a prominent feature. Very frequently the dykes are faulted along the quartz-reefs (in one place to a distance of about 50 feet), thus proving the latter to have been deposited subsequently to the intrusion of the former.

Woods Point.—In the Morning Star dyke,* which trends on the surface 54 degrees west of north, the quartz-veins penetrate the adjacent slates, and are rich near the contact. Several bore-holes were put down, which proved floors of quartz at lower levels, and show that the quartz-veins occur to great depths in the dyke-masses.

Various other localities might be referred to as at Alexandra, Testoe, Big-river, Carsely, Queenstown, etc., but sufficient data have been adduced to indicate the important part which these eruptive masses have played in the evolution of auriferous veins.

* Hornblende-porphyrite.

Contact-lodes.—In the north-eastern district, in an area hardly yet touched by systematic prospecting, it is estimated that there are fully 300 miles of contact-rocks intersected by auriferous quartz-veins. Two of the older gold-fields where some phases of contact-metamorphism of the sedimentary Silurian rocks and their associated auriferous veins may be studied in addition to the areas previously cited, are Maldon and Stawell.

Stawell.—At Stawell, the auriferous quartz-veins intersect a belt of country fringing the granite of the Black Range. The rocks are very much indurated or altered by contact-metamorphism, and the sediments are penetrated by numerous dykes of porphyrite and diorite. The auriferous quartz-veins strike from south-east to north-west, and generally underlie to westward at an angle of 45 degrees. In almost every instance, except the Magdala-cum-Moonlight, a flat reef has been found abutting against the vertical on the eastern side, with a northerly underlay, and the richest quartz has for the most part been found at no great distance east of the line of junction.

Maldon.—The Maldon gold-field is situated principally to the east of the granitic rocks at Mount Tarrengower. The alteration of the sediments has produced rocks of the hornfels type. A well-defined elvan traverses the gold-field, and in the case of the Derby mine is flanked on either side by auriferous veins. Fully 47 reefs have been described on this field, which strike north 12 degrees to north 30 degrees west. Several of the mines are now approaching a depth of 2,000 feet. Some interesting detailed information relating to the geological structure and many features of this gold-field will be found in a report by Mr. A. R. Moon, published as a special report by the Victorian Mining Department.

Organic Matter Influencing Deposition of Gold in the Silurian Sediments.

The writer has elsewhere* drawn attention to the fact that Mr. T. S. Hall, of Melbourne University, in a paper on the geology of Castlemaine, has shown that a subdivision of the Lower

* "President's Inaugural Address," *Geological Society of Australasia*, 1896.

Silurian beds may be made on the basis of the graptolite succession. The Lancefield beds were shown to be the oldest Ordovician strata. Above these, come the series at Bendigo, Chewton, Daylesford, etc., and still higher in the series, the rocks of Castlemaine and Darriwel. It was pointed out that so far as evidence is available, the quartz-reefs intersecting the Ordovician strata in Victoria are auriferous only when occurring in the soft beds of strata marked by the presence of such genera as *Phyllograptus*, or, in other words, deposition of gold is influenced by the organic carbonaceous matter of the graptolite-beds.

The writer does not think the evidence sufficient to justify the view that the Ordovician beds are auriferous only where the organic matter of the graptolite-beds would form a precipitant, because he believes that there is evidence of the existence of other organisms of a more perishable jelly-like nature, whose presence is now indicated only by certain ferruginous or other stains on the rock-masses, which nevertheless acted as a precipitant in certain areas where graptolites do not occur. He also holds the view that, what, in our ignorance of the real causes, may be denominated electro-magnetic action, has been a very important factor wherever metallic bases are in solution and in circulation, in effecting their precipitation on a suitable *nidus*.*

The writer may refer to an interesting feature connected with the auriferous-contents of the lodes in the metamorphosed areas, namely, the atomic ratios of gold to silver in certain formations. In the Lower Silurian, where gold is found nuggety, laminated, ragged, more rarely in scales, it varies from 22 : 1 to 6 : 1. In the crystalline schists, gold, laminated, ragged, and in scales, etc., varies from 4 : 1 to 1 : 1. In scales and grains in metamorphic slates from 5 : 1 to 3 : 1. Or the more nearly the formation approaches the crystalline schists in character, the more equal the ratio of gold to silver becomes. The following list of localities in Victoria and the value of the gold obtained therefrom will show this very clearly. Thus, in the metamorphic areas at Eskdale, Tallandoon, and Mitta Mitta North the value varies from £3 to £3 12s. per ounce; while in the Silurian areas at Smythesdale, Maryborough, etc., it varies from £4 to £4 3s. per ounce.

* See the writer's evidence before the *Royal Commission on Gold-mining in Victoria*, 1891.

Districts.		Value of Gold, per ounce.						
Alexandra	From	£3	17	6	to	£4	0	0
Beechworth	,,	3	18	6	to	4	0	0
Bendoc	,,	3	16	0	to	3	18	0
Gaffneys Creek	,,	3	16	0	to	4	0	0
Heathcote	,,	3	17	6	to	4	0	0
Kilmore, Reedy Creek	,,	3	17	6	to	4	3	0
Maryborough	,,	4	0	0	to	4	2	6
Mitta Mitta	,,	3	0	0	to	3	12	0
Omeo	,,	3	0	0	to	4	1	0
Smythesdale, Ballarat	,,	4	0	0	to	4	8	0
Wedderburn	,,	4	0	0	to	...		...
Woods Point	,,	3	10	0	to	4	2	6

Matrices for Gold.

It should be remembered, in considering the question of the geological age of the Victorian gold-deposits, that in addition to the well-known occurrences of gold in quartz-reefs and in alluvial deposits, the precious metal has been found in the following matrices in Victoria:—

In slates apart from quartz-reefs, at Redbank, Clunes, Castlemaine and Marong, Yahoo creek.

In sandstones forming pebbles, in the drifts of Rutherglen; and in sandstones at Castlemaine and Ramarooka.

In granites at Sandys creek, Mount Willis,* Granite Flat, Tabberabbera (Mornington). The gold occurs in thin quartz-veins in the granite of Sandys creek, and also in quartz-grains surrounded by felspar; and an assay of the latter by Mr. Newbery gave 19 dwts. 14 grains to the ton. In the Strathbogie ranges, a granite composed of felspar (orthoclase), quartz and black mica contained gold; it is traversed by veins of quartz, felsite and very fine granite; at the junction of these veins and the granite there is in many cases a wall formed of white mica and a pholeritic mineral; all the veins, as well as their walls, casing, and the decomposed granite through which they pass, have been proved to be auriferous; and also the solid undecomposed granite. Of course the gold may not be widely distributed and may occur in irregular or capricious shutes.

Ordinary pyrites, marcasite and pyrrhotite carry gold, at Yahoo creek and other localities. At Long Gully, some pyrites in a vein of calcite gave a yield of over 1 ounce to the ton.

* Note by Mr. E. M. Cairnes, F.G.S.

Gold occurs in wolfram at Swifts creek; and with bismuth at Wombat creek.

In diorite, north of Costerfield, generally in films and joints of rock. In diorites and felsite intersected by reefs of quartz, at Walhalla, Tanjil, Big-river, Alexandra, and Cannie creek. An assay of auriferous diorite from the Long Tunnel extended gold-mine, Walhalla, yielded: Gold, 5 dwts. 21 grains; and silver, 1 dwt. 23 grains per ton.

In diabase, at Heathcote.

In porphyritic dykes intersected by quartz-veins at various localities.

In basalt, at Mount Leura, near Camperdown.

It is noteworthy that the largest masses of gold in the reefs, as well as the largest nuggets in the alluvial deposits, occur where Lower Silurian rocks prevail.

Gold in Sea-water.

The experiments of Prof. Liversidge on the sea-water of our Australian coasts indicating the amount of gold as about ½ to 1 grain of gold per ton of sea-water, or from 130 to 160 tons per cubic mile, may be referred to as an instance of the actual presence of gold in solution at the present time. If we accept the data thus supplied by Prof. Liversidge, and previously demonstrated by Prof. Sonstadt, we shall have the enormous quantity of 75,000,000,000 tons of gold in the 308,710,679 cubic miles of ocean water. In all probability, the quantity existing in the ocean will vary at different localities, being greatest in those areas receiving the results of degradation of gold-bearing formations.

Meridional Belts of Reefs.

A feature which is common both to the Lower and Upper Silurian beds, no matter what the amount of local variation in the direction or formation of the quartz-veins may be, is the existence of meridional belts which come into view when the position of the quartz-veins are plotted on the map (Plate XXI.)—that is, there is a general meridional trend of the gold-bearing portions of the strata. This significant fact was emphasized by Capt. Panton, and Mr. C. W. Ligar, during 1858—by the former in the *Mining Journal of Victoria*, and by the latter in the *Transactions of the Mining Institute of Victoria*. In the latter publication the following pregnant remarks were made:—

With reference to the great national importance of the quartz-reefs of the colony, every circumstance tending to illustrate the general law under which they have been called into existence must be of interest. . . To the casual observer the relative position of the groups of what are termed paying quartz-reefs . . appear to be scattered over the country in an indiscriminate manner. . . I consider there is reason for supposing that such is not the case, but that they exist in lines running north and south in the magnetic meridian, and that these lines have generally a very remarkable equal relative distance from each other in an east-and-west direction. If so, significant facts are established for future exploration, and it may be that remunerative reefs will be discovered by a careful examination of these meridional lines, within certain limits of deviation to be determined on after future investigation. In this way, reefs of great value may be brought to light which evade the eye.

In pursuance of this hypothesis, Mr. R. A. F. Murray, the late government geologist, was able, after many years' study of the gold-fields, to map out a number of these auriferous zones and published some important observations, together with a summary of the scientific deductions made as to the origin of the auriferous quartz-veins by Mr. A. W. Howitt. In the light of more recent observations carried on during surface and underground surveys of the principal gold-fields—and also as the outcome of further petrographical studies the writer sees no reason to dissent from the general conclusions arrived at—on the contrary, the results of recent research in Victoria are confirmatory of Mr. Howitt's views. Mr. R. A. F. Murray remarks that:

Throughout both Lower and Upper Silurian areas the auriferous veins, whether traversing the rocks themselves or the intrusive diorite-dykes, occur in long belts conforming generally in direction to the strike of the Silurian strata. Within each belt are a greater or less number of different lines of quartz-reefs, and between the belts are varying widths of country in which little of no gold can be found, though the rocks are of the same character and the quartz-reefs as numerous as in the auriferous areas. Certain portions of the belts are richer than others, and intervals or breaks occur along them, where they appear to be non-auriferous; but when the different proved auriferous portions are marked on a map, their occurrence within tolerably well-defined parallels becomes very noticeable, and affords numerous suggestions for further exploration in search of both quartz and alluvial gold-workings. The auriferous belts are, as far as has been proved, narrower, and farther apart, and the lines of quartz-reefs fewer in number, and, as a rule, smaller in size, in the Upper than in the Lower Silurian rocks; but, on the other hand, the average yield of gold per ton of quartz from the former has hitherto considerably exceeded that from the latter.*

The forms in which gold occurs in the reefs are various. It is sometimes evenly distributed through the stone, but it is more frequently confined to some particular band, either on the foot or hanging-wall, or, more rarely, in the central portion of the vein or lode. The auriferous portions of the stone in some

* *Geology and Physical Geography of Victoria*, page 117.

places take the form of irregular disconnected patches, in others well-defined zones or shoots of varying vertical width, which dip at different angles northward and southward in the direction of the strike of the reef. The gold itself occurs in tolerably large lumps intermixed with quartz, in strings, ragged pieces, crystals, mossy aggregations lining cavities, and in fine specks. It is also found in mechanical combination with iron-pyrites, a mineral almost universally present in greater or less quantity in all quartz-lodes, especially below water-level. Besides iron-pyrites, copper and arsenical pyrites, galena, antimony and zinc-blende, are frequent accompaniments of auriferous lodes, and in many mines one or other of these is regarded as an infallible indication of the proximity of gold-bearing stone. . . .

Without entering into a description of the various different modes in which quartz-lodes and veins occur, the broad fact can be stated that they occupy what were lines of fissure in the Silurian rocks. As to how those fissures were formed in the rocks a general conjecture can be arrived at. It has been shown that the Silurian rocks (originally laid down horizontally) were crumpled, folded and contorted so that their bands finally assumed positions approaching the vertical, and that whatever may have been the cause, the forces operating were such that the longitudinal axes of the corrugations took in Victoria, for the most part, an approximately meridional direction. Such movements could not take place without, in addition to the corrugation, considerable faulting, fissuring and great local displacements, and the lines of fracture, naturally following those of least resistance, coincided in general direction with the strike of the schistose rock-bands.

It is scarcely to be imagined that all the fissures now occupied by quartz-veins were formed within one short period. No doubt most of them resulted from movements connected with or closely following the corrugation of the strata, whether that process was accomplished quickly or slowly; but with succeeding movements further fissures and displacements were effected from time to time, thus rendering the systems of fissures or lines of fracture more and more complex. The existence in Upper Palæozoic rocks of quartz-veins traversing conglomerates, which are themselves partly composed of rounded pebbles of vein-quartz, is in itself a clear proof that the formation of quartz-veins in fissures was not confined to the Silurian rocks, although it attained its extreme development in them. At the same time, it would appear that most of the fissures occupied by quartz-veins in Silurian rocks in Victoria were formed, and occupied by their contents, prior to the formation of the Upper Palæozoic rocks.

With regard to the direction and extent of the fissures, much depended on the character of the rocks they occurred in. In evenly-bedded slates, the fissures would generally be regular. while in diorite-dykes the shrinkage-cracks would naturally be irregular, though the fissures, if any, along the walls of the dykes would be influenced, as regards regularity or otherwise, by the character of the containing rocks. In one case, a clean fissure or split between two parallel rock-bands would be effected. In a second, the fissure, owing to some conditions in the directions of the operating forces, or the tenacity of the rock-bands, would follow the planes of stratification, either horizontally, but not vertically, or would intersect them obliquely in both directions. In a third instance, an abnormal displacement would cause a fissure of which one wall was clean—that is, the plane surface of a rock-layer—and the other wall irregular, on account of the plane of the former crossing obliquely the basset edges of the layers in the latter. Numerous other cases and combinations might be instanced, but the above are the

principal, and serve to illustrate the phenomena now observable in mineral lodes and veins. Fissures also occurred, along different portions of which all the conditions mentioned were developed. The course of a fissure diverged from between two parallel bands, and passing downwards, or laterally through one wall, established the conditions described in the second case, whence it passed into the third, etc. Where plutonic or hydrothermal action resulted in the injection of dykes, we find that while some of those dykes found their way along the lines of least resistance or with the strike of the rock-bands, others intersected the latter across their line of strike, either obliquely or at right angles.

Admitting generally that the fissures resulted from movements of the earth's crust and the fracturing thereby of the rock-masses, the next consideration is the method by which the quartz-veins were formed into fissures, and the associated minerals conveyed and deposited in or with the quartz. In the first place, it is known that silica, the principal, or nearly the sole constituent of quartz, is capable under certain conditions of being held in solution and of being deposited from that state in various forms, crystalline, concretionary, laminar, etc.*

Mr. A. W. Howitt's views, which have been quoted *in extenso* by Mr. Murray,† are as follows:--

(1) I assume the existence of gold in solution in the Palæozoic seas.

(2) The Silurian sediments, during their formation, necessarily included a large amount of sea-water (organic matter may have precipitated gold in a metallic state, and in a finely-distributed condition, throughout and in these sediments).

(3) This included sea-water could not escape until the sediments were raised above sea-level.

(4) The geological evidence shows that before being so raised they were folded, compressed and depressed within the influence of the internal heat of the earth. It is immaterial whence this heat was derived—possibly due to the molten interior, and heat resulting from motion in the crushed sediments.

(5) The sediments were then invaded by molten rock-masses from below; were metamorphosed, melted and absorbed as to their lower portions; the molten material was forced upwards through the line of least resistance to the surface, and gave rise to the Palæozoic volcanoes, *e.g.*, of the Snowy river. The great masses of molten material on final consolidation are represented by the granitic rocks underlying all Victoria.

(6) The salts in solution in the sea-water included in the sediments, and the materials of the sediments themselves, reacted upon each other under the influences of heat and pressure.

(7) The mineralized waters would find passage through the contact planes of the igneous and sedimentary rocks, and by fractures in the strata, etc.

(8) On the cooling down of the rocks, the waters would likewise lessen in temperature, and deposit their metallic and mineral substances which they had leached out of the sediments; would deposit them in the contact-planes, faults and fissures. Faults which had been penetrated by dykes would also afford passage to such waters, and to sublimations, *e.g.*, Cohens Reef and also Steamboat Springs of California.

* *Geology and Physical Geography of Victoria*, page 118.

† *Ibid.*, pages 122-124.

(9) All the saline solutions in the Palæozoic seas would enter into re-actions, and even if the gold had been reduced by organic substances, it would, I think, be again chlorinated on the regeneration of the felspars out of the materials of the sediments and the alkaline chlorides and chloride of calcium in solution.

It seems to me, therefore, probable that we may refer the formation of auriferous veins and metalliferous lodes, generally occurring in the Silurian and Devonian formations, to plutonic and volcanic action, which prevailed about the close of the Silurian period and onwards, until our geological record closes in the Upper Devonian. But we must also take into account a secondary process which is always going on in the re-actions produced by meteoric waters percolating from the surface downward; this process is partly one of decomposition and partly of concentration.

The conclusions I arrive at are, therefore (1) That the gold has been collected out of the sediments during the plutonic and volcanic action in Palæozoic periods; and (2) that it has been (at the surface) undergoing concentration, partly by the removal or decomposition of metallic ores. We know that auriferous reefs very frequently, if not almost always, occur in bands along the strike of the sediments. In accordance with the above views, I suggest that these bands represent extensive fractures, communicating downwards with the planes of contact of the igneous and sedimentary formations. Such extensive fractures would give passage to heated mineralized waters and to sublimations. As to these bands, I think we may assume the following:—(1) The folding and compression of the Silurian rocks was consequent upon the contraction of the earth's crust through cooling of the globe. (2) That fractures would most probably occur along the axes of anticlinal and synclinal folds. (3) The pressure of a folded and depressed portion of the earth's crust upon the molten material beneath would afford a sufficient *primum mobile* to produce the upward thrust of liquid rock-masses through fissures, and generally against the overlying sediments. This pressure, produced by the contracting crust, would suffice to produce volcanic outbreaks, without calling in aid waves of the molten interior, etc. Nor could steam be called in to produce the upward motion of the molten rock until it (the rock) rose to within such a distance of the surface that the pressure of the column of rock (or of molten rock) was no longer sufficient to keep water fluid.

Assuming Mr. Howitt's views to be correct, Mr. Murray remarks that:

The occurrence of auriferous quartz-veins in belts may be due to the circumstance that a greater amount of gold was deposited in certain sets of layers than in others, and that when the rocks were uplifted from a horizontal to a vertical position, those bands which contained most gold yielded the largest supply for deposition in the quartz-veins, while in others containing little or no gold only poor or barren quartz-veins were formed. I am aware that many difficulties will have to be surmounted before the above theory can take the position of an universal explanation; but in the meantime it claims to be a good working hypothesis, founded on well-digested information, and likely at no distant date to rank—subject to a few modifications—among the established deductions of science.

Later discoveries go to confirm the prediction of Messrs. Panton and Ligar endorsed by Mr. Murray in a remarkable degree, so that now fully thirty of such auriferous belts may be mentioned. The writer can only refer to the localities intersected by them as an instance of the fact, without attempting a description of the local details. Of course, in tracing these belts on the map (Plate XXI.) their continuity will be found to be broken in places by the granitic, basaltic and Upper Palæozoic rocks.

No. 1 belt, commencing in the western portion of the colony, extends south from Balmoral, where alluvial auriferous deposits occur, but as yet no reefs.

No. 2 is on the Upper Glenelg, east of the Black Range, where several reefs have been prospected.

No. 3. On the eastern side of the Grampians, a belt may be traced from Moyston to Fryingpan, where both quartz and alluvial workings occur.*

No. 4. From Ararat, through Great Western, to Stawell, comprising both alluvial leads and auriferous quartz-veins. The Hopkins valley lead originates within this belt.

No. 5. East of Stawell, a belt extends from Navarre, in the Pyrenees, southward to Buangor. There is good scope for loaming along the western slopes of the Pyrenees within the limits of this belt.

No. 6. From St. Arnaud (where there is a group of three well-defined lines of reef—one of these, the Lord Nelson, being mined to a depth of over 1,600 feet with highly payable results) an auriferous belt extends southward through Stuart Mill to Redbank, Moonambel, Percydale, and from the Avoca valley across the Dividing Range past Elmhurst to Beaufort and still farther southward to Lillie Plains, where deep alluvial ground occurs right across to the Skipton diggings.

No. 7. Still farther east a belt may be traced from north of Bealiba through Homebush and Avoca leads to Evansford, Carngham, Scarsdale and Pitfield Plains. In the latter, recent borings suggest that a deep lead may be found to extend beneath the basaltic plains towards Lake Corangamite on the west.

No. 8. From Ballarat, a belt extends northward through Cres-

* It is within this belt, that recent discoveries have been made near Ararat in the Grampians.

wick, Clunes, Maryborough, Carisbrooke, Majorca, and Timor, Dunolly, Tarnagulla, Moliagul to Wedderburn. Referring to this belt, Mr. Murray remarks that within this great auriferous zone he would include the gold-fields of Inglewood, Tarnagulla and Kays diggings, north of the plains of the Loddon valley, and to the south the gold-fields of Smeaton, Kingston, Creswick, Ballarat, Buninyong and the Durham. The last-named localities are continuous with one another as regards auriferous character, there being no break from Durham to Smeaton, a distance of 25 miles from north to south in the alluvial gold-workings, over a width of about 4 miles from east to west. The belt of the Leigh river has been profitably worked 20 miles south from Durham, and auriferous gravels have been traced from its banks under the plains south of Mount Mercer, where the further continuation of the Durham lead is sure to exist. It is, therefore, Mr. Murray thinks, quite likely that the belt of Silurian rocks extending southward from Ballarat may be found to have regained its auriferous character, and that the deep ground resting on it beneath the basalt may be as rich in gold as those to the northward. As regards the portion between Smeaton and Tarnagulla, there is every reason to believe that the belt retains its character from the Madame Berry line, a distance of 30 miles to Tarnagulla, and that all the alluvial leads in its course will prove profitable. On a smaller scale, the flat alluvial country along the Bulbul creek, between Tarnagulla and Inglewood, is likely to prove auriferous in the vicinity of a line between these two places.

No. 9. From Inglewood (where a number of reefs have been worked to shallow depths, four distinct lines being traceable for a distance of 4 miles) a belt of auriferous country certainly extends through Newbridge, Baringhup, Campbelltown, Bullarook and east of Mount Buninyong to Elaine.

No. 10. From Maldon southward through Muckelford, Daylesford, Ballan and Steiglitz (several of the mines at Daylesford have been carried to a depth of 1,800, and there are no geological reasons why a highly auriferous zone should not be met with at lower levels than the present lowest workings). Similarly, the Steiglitz gold-field should yield profitable returns as deep as that now worked at Ballarat.

No. 11. A very important belt extends southward from Bendigo, through Castlemaine, Chewton, Elphinstone and Blackwood,

towards Bacchus Marsh. Castlemaine has long been known for its surface auriferous wealth; and it is believed that deep mining will reveal, between the 1,000 feet and 3,000 feet levels, a payable auriferous zone, and that at these deep levels saddles, similar to the Bendigo field, may be met with. Of course, the structural feature of the reefs will depend on the direction and extent of the compressive forces acting on the strata. It is probable that the granite-masses between Castlemaine and Bendigo have played an important part in the genesis of the reef-formations.

No. 12. East of Bendigo, recent mining developments are disclosing the existence of a belt extending from Goornong, through Ellesmere (Fosterville) to Axedale, and farther south to Redesdale, and on towards Macedon, intersecting the basaltic leads east of Kyneton and Malmsbury.

No. 13. From Runnymede, through Heathcote (where gold has recently been found in quartz-veins intersecting a diabase-dyke, near the junction of the Lower and Upper Silurian formations, which rest upon still older Cambrian rocks) to Lancefield, Romsey and Riddells creek.

No. 14. An important belt, characterized by the occurrence of antimony-ore in association with the auriferous quartz-veins passes from Redcastle, Costerfield, Pyalong, Kilmore (where scheelite has been found), on towards the Morang district, near Melbourne.

No. 15. Another similar antimony-bearing belt extends from Rushworth (where cross, or east-and-west, lines of reef occur) through Whroo, Mitchelstown, Reedy creek (Broadford), Whittlesea, west of Queenstown, east of Oakleigh, and on to Tabberabbera, on the Mornington peninsula, where quite recently gold was found in granitic rocks.

No. 16. From Murchison southward through Yea and on to Emerald, east of the Dandenong Ranges.

No. 17. From Merton to Alexandra, Marysville, and southward to Neerim, intersected by dyke-formations.

No. 18. An important belt extends from Dookie, where ironstone-deposits occur, south through Maindample, Darlingford, Frenchmans creek, on the Big-river, through the heads of the Yarra, to the west of Mount Baw-baw, and on to the Tanjil, extending also, in all probability, beneath the South Gippsland Mesozoic beds to Foster and Wilson Promontory.

No. 19. Another, and perhaps the most interesting of all the belts, extend southward from Benalla, through Toombullup, Jamieson; Lauraville, Woods Point, Matlock, Jericho and Walhalla. This is, *par excellence*, the belt of dioritic dykes, extending uninterruptedly for over 70 miles. The dykes run at various angles with the strike of the enclosing strata. When they are parallel, or nearly so, the reefs are more persistent, and the shoots of gold longer, than in those cases where the dyke cuts the strike of the strata nearly at right angles. In the east of the Walhalla auriferous belt, there is a large area covered by Devonian rocks, which have not yet proved payably gold-bearing. Although two minor belts may be traced—one from Camerons creek on the Howqua river, southward to the east of Mount Useful, and on the Siaton, and the other from near Briagolong (Gladstone creek) northward through the Wonnangatta valley to the heads of the Buffalo river.

No. 20. From Rutherglen, where deep alluvial leads occur, a belt may be traced in a south-south-easterly direction through Everton, Myrtleford, Buffalo river, across the Dividing Range, to the Wongungarra valley and Crooked river.

No. 21. From Barnawartha, through Woorragee to the east of Beechworth, on to Bright district, Harrietville, west of Mount Hotham, to the head of the Dargo, over the Dargo High Plains to Grant and Lower Dargo. It is on this belt that the highest altitude at which auriferous veins have been found is attained, as on the western side of Feathertop Ridge, at 6,000 feet above sea-level.

No. 22. Still farther east, a very extensive belt stretches from Bethanga, on the Murray, through Eskdale, Snowy creek, and Mount Wills, Livingstone, Cassilis, Haunted Stream, and to Monkey creek, near Bruthen.

No. 23. From Granya, through the head of the Dark river, to the Gibbo river, and in all probability through the head of the Tambo, southward towards Mount Tara.

No. 24. From Corryong through Wheelers creek and Buckwing, to the Limestone river, and the heads of the Buchan river.

No. 25. On the eastern side of the Snowy river, recent mining explorations suggest several auriferous belts, as under:—From McLachlans creek, on the border-line between New South Wales and Victoria, through Deddick, Mount Bowen, and the heads of

the Yalma, west of Mount Ellery, and on to Cabbage Tree creek.

No. 26. From Bonang, through Boulder creek, to Club Terrace, Lower Bemm, and Pearl Mount on the coast.

No. 27. From Mount Delegate, through Bendock, over the Coast Range, to the eastern heads of the Bemm and western heads of the Cann river valleys.

No. 28. On the extreme eastern portion of the colony, from Mallacoota Inlet, across the Genoa valley, into New South Wales.

Enough has been stated to demonstrate beyond the possibility of doubt the enormous extent of the gold-bearing belts of strata, and that there is practically an inexhaustible supply of gold yet to be won: not only in following the downward prolongations of the reefs already discovered, but in renewed search for further surface-outcrops along the extension of the belts which the writer has indicated. No theoretical speculations respecting the genesis of gold-bearing veins need militate against successful mining enterprise in those districts where the downward prolongations of the auriferous reef-formation are at present a matter of conjecture. The fact remains that from the highest surface-altitudes to a depth of 3,500 feet below sea-level gold-bearing strata undoubtedly exist.

The Structural Features of Two of the Principal Gold-fields.

Ballarat Indicator.—The characteristic features have been clearly and ably described in a report on the Ballarat East portion of the Ballarat gold-field, by Mr. E. Lidgey, who remarks "that the peculiar features of this portion of the gold-field are the occurrence of so-called indicators, and the exceedingly rich patches of gold met with at the intersection of the indicators and the narrow quartz-veins." These indicators are usually thin beds of dark-coloured shales or slates, formed of a carbonaceous mud containing a large proportion of iron sulphide, parallel and nearly vertical. These indicators receive locally different names, such as—The Indicator, a narrow band of dark slate, showing cleavage-planes, and containing a large percentage of pyrite distributed through it. When in contact with quartz, arsenical pyrites, galena and sphalerite occur. The Pencil Mark resembles a dark pencil-mark drawn on the light-coloured slates, rarely more than ¼ inch thick.

The quartz-veins on the indicator-belt occur usually in thin veins, crossing the strata at all angles. Veins of most interest to miners usually cross the country-rock at nearly right angles, underlie slightly to the east, with a northerly pitch in most cases. The quartz is usually whitish. No dig or pug is found on either wall, unless a later fault has intersected the vein at a small angle, and runs parallel with it for a short distance. The gold is found at points where the quartz-veins cross, and slightly fault the indicator, often occurring in solid masses many ounces in weight. The slight changes in the country-rock known as "heads" or "headings" influence the deposition of gold in the quartz-veins.

In the veins on the Indicator, the gold usually is in fairly large pieces, associated with much pyrite, marcasite, a little galena and sphalerite. At the Pencil Mark, rather more galena and less pyrite is found.

At Ballarat there are at least four well-defined lines of reef, such as the Guiding Star, Star of the East or Consols, the Indicator on the Llanberis and Speedwell line, and the Fire Brigade line. It is believed that the indicator-belt of country on the eastern side of the field will be found to extend past Creswick and Allandale towards the Moolort Plains. The Silurian slates and sandstones of the Ballarat gold-field differ slightly in composition from those at Bendigo, and are intruded into by granitic and felsitic dykes in places. The folds in the strata are not so readily distinguished as at Bendigo, and there is a marked absence of the graptolites which characterize the Bendigo slates.

Other Indicators.—At Rokewood Junction, the indicator is a soft slaty band, somewhat ferruginous, frequently soft and clayey, varying from brown and grey to nearly black, in contact with the hanging-wall of the reef. The gold occurs in most abundance in 1 or 2 inches of friable stone in contact with the slaty band, and generally in masses up to several ounces in weight.

At Creswick, Nuggety Gully, the indicator consists of a yellowish-brown, fine-grained, soft, earthy shale, of somewhat soapy texture, with thin brown ferruginous veins. At the intersection of the quartz with this band, the richest deposit of gold occurs.

At Wedderburn, the indicator consists of an orange-coloured streak about $\frac{1}{16}$ inch thick, scarcely distinguishable from the slates in which it occurs. Again, it resembles a miniature reef,

sometimes laminated. The principal indicator, which has been followed for over a mile, consists of three parallel veins of iron-stone or grit, about ⅛ inch thick and 4 inches apart. On the Champion reef, the indicator consists of a thinly laminated unctuous dark grey clay from 5 to 7 inches thick. The quartz-veins crossing this indicator are very rich, the gold occurring in coarse nuggety pieces.

At Korong Vale, Nil Desperandum, a band of nodular micaceous schist, from a few inches to 2 feet in width, between walls of hard sandstone, constitutes the indicator.

At Elaine, the indicator is a thin band of highly pyritous black shale. When the lode intersects it the latter carries gold. In another place, a band of yellowish-white concretionary nodules, with gold on the face of the concretions, is considered as an indicator.

At Welcome Gully, near Daylesford, wherever the quartz-veins come in contact with a small slate-band of soapy texture, usually of an olive colour, but often grey to black, and more or less ferruginous, the former is highly auriferous.

Bendigo Saddle-reefs.—In a valuable memoir on the Bendigo gold-field, by Mr. E. J. Dunn, published by the Mining Department, the features of the saddle-reefs of Bendigo are described. Attention had, however, been previously directed to the salient features of the field by Mr. W. Nicholas, formerly an officer of the Mining Department, in the mining journals. Mr. Dunn remarks that—

> The most peculiar feature about the quartz-veins of the district is the occurrence of the so-called "saddle-reefs." These bodies of quartz of lenticular form . . . . formed in cavities caused by the bending over sharply of the unyielding rocks of the region. . . . The extensions east and west of the centre country of the quartz downwards from the saddle-reefs are known as legs, the latter often thinning out rapidly in the form of a wedge, in some cases extending to a depth of 300 feet or more below the saddle. The legs are seldom more than 3 or 4 feet across; the saddles are often 40 to 50 feet across, that is, measuring horizontally over the saddle. The extension of the apex of the saddle is called centre-country; it runs generally parallel with the strike of the strata.

The principal reefs in this field occur in the fissures produced by the arches formed by a buckling of the strata into a series of folds; or, in other words, the prominent feature of the field consists of numerous more or less parallel axial lines, having a strike

of north 16 degrees west, along the course of which the great mass of slate and sandstone-rocks are bent over into a series of anticlines, with corresponding synclines or troughs between them. The dip of the beds to the east and west is about 60 feet. These axial lines or centre country do not continue horizontal for any distance, but have an endlong dip or pitch. The reefs are called saddles, and thicken and diminish in size as they are traced along the axial lines.

A succession of saddles occur at different levels, not as a rule immediately one below the other, but shifted to one side, principally to the west. In a limited area about 7 miles long by 3 miles wide, there are no fewer than twelve distinct lines of saddle-reefs, known as centre-country. Mining operations have extended to a depth of over 3,000 feet with profitable results. The deepest shafts on the gold-field include:—

Names of Mines	Depth. Feet.
Lansells 180 Mine	3,350
New Chum Consolidated	3,267
Lazarus Company	3,210
New Chum and Victoria	3,100
New Chum Railway...	3,037
Shamrock	3,000

Although the reefs in the central area of Bendigo occur in the form of saddles, yet to the north-west, as at Marong; north, at Sebastian, Raymond, etc.; or south, at Mandurang, they assume different forms. At Marong, where gold occurs in the slates near the surface, slightly inclined or even vertical veins occur, forming irregular seams of quartz in a band of sandstone. At Mandurang, towards the Crusoe reservoir, flat veins occur; and where such veins intersect a particular band of strata, which contains a thin, almost parallel band or seam of slightly different mineral composition from that of the enclosing strata, the richest gold is found. The writer has no hesitation in affirming that there is work for centuries to come, not only in exploiting the saddle-formations down to as great a depth as 4,000 feet, but in tracing the auriferous belt to the north and south, or developing such parallel belts as Ellesmere to Axedale on the east, or Marong to Lockwood on the west. It is estimated that, making due allowance for the increased cost of haulage and deep sinking, quartz containing 5 dwts. of gold to the ton can be made to pay in the deep levels at Bendigo.

A petrological examination of the lava-dykes of the Bendigo gold-field, and of the slates and sandstones at the deep levels in Lansells 180 mine from 270 feet below the surface to 3,136 feet, proved that the lava belonged to the class of Tertiary dykes known as limburgite. All the sedimentary rocks have been affected by a form of metamorphism which is very general in the Silurian formations in Victoria, producing a more or less complete molecular recrystallization of the paste or mud of the original sediments, while leaving the included fragments of quartz, felspar, etc., almost intact. Much free silica had been redeposited in these beds, either surrounding quartz-grains or forming minute veinlets which, so far as the microscopic character of the quartz was concerned, could not be distinguished from the quartz of the auriferous saddle-reefs.

It is significant that the majority of the gold-bearing veins of the world are associated with the older rocks. Yet numerous examples of auriferous deposits in the younger rocks are not wanting, for instance:—In the Jurassic strata of the Saint Arnaud, Switzerland, an auriferous vein occurs. The Liassic limestone near Graves in Westphalia is reported to be auriferous. The majority of the Hungarian and Transylvanian gold-veins cut through Tertiary rock. Traces of gold have been found in the Miocene sandstones and conglomerates of the valley of the Aar. At the village of Vöröspatak, in Western Transylvania, over 300 veins were worked in Eocene sandstones. The auriferous slates of the Californian belt of the Sierra Nevada, U.S.A., are considered to be of Jurassic age. The rhyolites and andesites of the Pacific Coast of the U.S.A. are known to be auriferous. In Colorado, at Cripple creek, gold occurs in dykes and quartz-veins in rhyolite and phonolite, and in the vents of filled-up craters and dykes of andesite, rhyolite and trachyte.

Proofs that Deposition of Gold is still going on.

The occurrence of gold with pyrites in the driftwood of the deep leads and also in the charcoal of the same, in the pyrites cementing the quartz-pebbles of the drift, or forming stalactitic masses in the lower side of the basalt over the leads, may be taken as an indication that the deposition of gold has not ceased.

Further evidences may be adduced, such as gold found not only in mine-water, but in the incrustations from steam-boilers fed with

mine-water, and also in the secondary pyrites coating the joints and filling fissures in the quartz of lodes.

Middle Devonian.

The Devonian formation consists principally of isolated beds of marine limestones as at Buchan and Bindi; and sandstones, etc., etc., as at Tabberabbera. The limestones contain an abundance of corals, shells, and some fish-remains. At Buchan, the limestones overlie diabase rocks and porphyries, calcareous breccias, etc.; and at Tabberabbera, micaceous sandstones, shales and quartzites. These beds have been subjected to considerable fractures and in some cases to foldings since their deposition, and are penetrated by eruptive dykes.

Upper Devonian.

The Upper Devonian consists of massive beds of sandstone, conglomerate and shales interbedded with contemporaneous lava-flows (melaphyre, diabase, porphyry, etc.). At Freestone creek, these Devonian rocks are intersected by siliceous and felspathic dykes. In the conglomerates at or near the areas intersected by the eruptive dykes, gold has been discovered, and this has lent support to the view that the Devonian conglomerates were themselves of an auriferous character.

Carboniferous.

In the Mansfield district, certain red sandstones in which Mr. George Sweet has discovered numerous fish-remains in the vicinity of a *Lepidendron*-bed were described by Sir Frederick McCoy as probably Lower Carboniferous.

Recent discoveries of some fine gold in the conglomerates at the base of this formation, which resembles lithologically some of the Upper Devonian beds, are also adduced as an evidence of contemporaneous deposition of gold, but it is by no means certain that, even in this case, the origin of the gold may not still be traced to the action of certain eruptive dykes traversing the area. Still, more recent discoveries of gold on the slopes of the Grampian ranges in western Victoria are by some persons also attributed to contemporaneous deposition. From certain observations that the writer has made in this region he attributes the origin of the gold to the action of certain masses of quartz-mica-diorite, and quartz-

diorite, or of porphyrites intruding into the sandstones, which are presumably of either Lower Carboniferous or Permo-Carboniferous age. Referring to the deposition of these Upper Devonian and Lower Carboniferous rocks it is remarked that—

> The existence of these rocks is evidence of a submergence of this portion of Australia to not less than 6,000 feet below existing level. Such a submergence would not only leave two or three points of the Australian Alps above water-level; but at the time referred to the main mass of Lower Palæozoic rocks, constituting the rock-foundation of the country, was infinitely less attenuated than now; in fact, the Silurian and granite-mountains now forming our main range from Ararat to the New South Wales border are, so to speak, but the stumps and roots of a mighty mountain-chain, whose crest towered high above the Palæozoic seas. Deposits were formed by those seas only on the submerged flanks of that chain, or in deep indentations and fiords eroded by encroaching littoral action, aided by glacial and fluviatile denudation operating on the land-surface. It is not probable, therefore, that the main ridge of that epoch was submerged beneath the Palæozoic seas; though it is likely that the denudation of the period, littoral, fluviatile and glacial, played an important part in shaping the outlines of the principal indentations and projections now observable in the Lower Palæozoic rocks of our mountain-chain. Whatever fringing-deposits were laid down along the then coast-line from Ararat to the Macallister have been since entirely removed.

Mesozoic Formations.

It has been pointed out that—

> In our Mesozoic rocks we have evidence of a depression of this country to not less than 2,500 feet below existing level, and in the geographical boundaries of the areas occupied by them we find signs of further denuding action, which materially influenced the configuration of the Silurian areas. Littoral denudation in Mesozoic times eroded the flanks of the Silurian rock-masses up to Morwell and Toongabbie, in Gippsland to the bases of the Grampians, and probably to Ararat. The crest of the main divide was, by that time, much reduced by denudation, though still far loftier than now.

Certain glacial conglomerates at Bacchus Marsh, Heathcote, Coliban valley, Carisbrooke, and other portions of the Loddon valley, are undoubted evidences of ice-action during early Mesozoic times.

Triassic.

Under this heading have been provisionally classed the glacial conglomerate-beds above referred to and associated false-bedded sandstones containing imprints of such recognized Triassic plants as *Gangamopteris*, *Schizoneura*, *Ptilophyllum* and a *Tæniopteris*. In the absence of such evidences of an early Mesozoic flora, the glacial beds and associated sandstones might easily have been

classed as lithologically similar to some of the Palæozoic rocks such as the Permo-Carboniferous beds of India, South Africa and a portion of New South Wales. There is no evidence that these Triassic glacial conglomerates are of an auriferous character.

Jurassic.

Extensive beds of felspathic sandstones, shales, subordinate beds of coal, and also underlying beds of agglomerates and conglomerates occur in South Gippsland, Cape Otway and Wannon districts. These beds have yielded an abundant fossil flora of such characteristic genera as *Alœthopteris, Sphenopteris, Sagenopteris, Podozamites, Brachyphyllum, Palissya, Baiera, Phyllotheca* and *Tœniopteris*, all the species being allied to Indian forms, together with three species of *unio* and (two?) freshwater fishes.

These Jurassic beds are intersected in South Gippsland by dykes of gabbro, dolerite and basalt, and in places, near the gabbros, small veins of quartz have been observed, but none are known to be auriferous. In the Cape Otway district, dykes of a more acid nature occur and in their vicinity a little gold has been found; not in the rocks, but in the gravels and bouldery washes overlying them. Recently, however, some gold has been detected in the coal-seams, apparently deposited along the fine joint-lines in which occur thin films of calcite. There is no evidence that this gold was originally deposited in the carbonaceous beds, but it may have been deposited by infiltration of surface-waters. Auriferous conglomerates and gravels which have been distributed in the valleys eroded from the Jurassic rocks in Middle Tertiary times overlie the former beds in many places. But they were in all cases formed by degradation of adjacent areas of Silurian rocks, and apparently derived therefrom by subaerial denudation.

Eocene or Oligocene.

These beds are represented by the lowest members of the Tertiary system in Victoria. Along the coast and in some valleys for some distance inland, as in the Glenelg and its tributary, the Wannon, it includes grey clays with septaria, beds of limestone, etc., of marine origin, which Sir Frederick McCoy fixed as Oligocene and Prof. Tate as Eocene, from the character of its rich assemblage of fossils. Also certain quartzites and siliceous conglomerates which included deposits of hard shale, containing plant-impressions, as in portions of the Latrobe valley.

The fossils are very numerous, and include representatives of the classes zoantharia, echinodermata, palliobranchiata, lamellibranchiata, gastropoda, scaphopoda, pteropoda and cephalopoda. Many of the species, however, range up into the Pliocene deposits. The following are recognized as characteristic Eocene species by Mr. Dennant:—*Aturia Australis, Murex velificus, Ranella Prattii, Triton tortirostris, Nassa Tateii, Marginella Wentworthii, Cancellaria varicifera, Daphnella gracillima, Cypræa gigas, Trivia avellanoides, Entalis subfissura, Dimya dissimilis, Pecten zitteli, Plagiarca cainozoica* and *Terebratula vitreoides.*

In conjunction with Mr. Mulder, of Geelong, Mr. Dennant has described the Eocene deposits at Shelford, and quite recently has recorded the first occurrence of marine Miocene deposits in the central parts of the colony. It overlies basalt, which is alleged to be Miocene, or older; and underneath the basalt is auriferous drift. This discovery may enable these gold-bearing drifts to be correlated with the marine deposits now so closely studded along the coast-lines.

Mr. Dennant also divides the Muddy creek beds into Miocene and Eocene. In his observations on the Tertiary and post-Tertiary geology of south-western Victoria, he has divided the post-Tertiary beds into Upper, Middle and Lower; the older Tertiaries of Bairnsdale are grouped by him as Eocene. In conjunction with Prof. Tate, he has published a series of papers on the "Correlation of Marine Tertiaries of Australia." In Part I., certain beds at Spring creek, Camperdown, Gellibrand, are classed as Eocene, and in Part II., the Cape Otway beds are referred to as probably older than the other Eocene deposits in Victoria.

Miocene.

Beds of Miocene age are extensively developed in Victoria, and include deposits due to marine, lacustrine and fluviatile agencies. In many localities inland from the coast they are covered by volcanic rocks, basalts, etc.

The marine formation consists of whitish and yellowish-brown sandy calcareous layers, sandy ferruginous layers, coralline limestones and calcareous clays, as found at various points along the coast from the Glenelg to the Gellibrand river, Port Phillip, Western Port, Sale, Bairnsdale, Lake's Entrance, and Snowy river. They also extend along the valleys of the Glenelg, Hopkins and

Curdies rivers, north of Cape Otway ranges, up the Moorabool and Leigh rivers, and between Melbourne and Station Peak, also underlying the Murray Plains to the north-west.

Ferruginous gravels and conglomerates, due to littoral action, occur in many localities. The deposits due to lacustrine action consist chiefly of clays and lignites. Mr. Murray has referred the Lal Lal, McKerley's creek, and Meredith lignite and brown-coal deposits to the Miocene period. Also other deposits in the Latrobe valley, as at Yarragon, etc.,* which are overlain by volcanic rocks. So too the ferruginous clays containing fossil leaves on Dargo and Bogong High Plains, and the siliceous conglomerates, covering a large area between 200 and 800 feet above sea-level. Some of these, however, may be referred to the Eocene, as previously stated.

From the occurrence of plant-remains, pronounced by Sir Frederick McCoy to be of Miocene age, and found in the indurated clays underlying the basalts of the elevated table-lands in the Australian Alps, it was believed that the basaltic formations were not older than Miocene. This view will have to be modified, and the oldest auriferous drifts of the colony in all probability must be referred to the Eocene. These palæontological evidences of the age of the Tertiary formations may seem to be of little moment, but when we are discussing the age and position of the alluvial gold-bearing deposits of the colony, their full significance will be seen.

At various localities inland, as in the Latrobe valley, the Jurassic deposits are overlain by siliceous conglomerates and indurated clay, containing leaf-impressions of an Eocene facies These are in turn covered by sheets of basalt, hitherto classed as Miocene, but which, as recent research tends to show, must now be included in the oldest Tertiary formation.

A rich assemblage of marine fossils has been described from the Victorian Miocene beds by Sir Frederick McCoy, Prof. Tate, Mr. Dennant, Mr. Pritchard, and others. A few leading or characteristic genera may be mentioned:—*Squalodon*, cetotolites (ear-bones of whales); *Carcharadon*, *Clypeaster*, *Monostychia* and *Pericosmus*. Mr. Dennant considers the following characteristic mollusca as Miocene:—*Peristernia approximans*, *Nassa crassigranosa*, *Cancellaria wannonensis*, *Drillia cochlearis*, *Pelicaria coronata*, *Scalaria triplicata*, *Leiopyrga quadricingulata*, *Barnea tiara*, *Myodora corrugata*, *Psammobia Hamiltonensis*, *Cytherea pauci-*

* The writer has recently referred these to Eocene.

rugata and *Trigonia Howittii*. Plants:—*Cinnamomum, Laurus, Salisburia*, etc.

Pliocene.

The Pliocene formation consists of beds deposited by marine agency and those due to fluviatile action.

The marine beds consist principally of fine and coarse ferruginous sandy beds, gravels, conglomerates, sands, clays and shales, found resting either on older volcanic Miocene beds or on Mesozoic or Palæozoic rocks. The marine beds extend along the coast from Glenelg to Portland, Warrnambool to Gellibrand, flanking the Mesozoic ranges of Cape Otway, South Gippsland. Ferruginous sandy and gravelly beds prevail from Melbourne to Frankston. Some of the gravels and conglomerates passing under the post-Tertiary deposits of the Murray Plains, north of the Dividing Range, are of Pliocene age, and are due to littoral marine action. Many of the Pliocene deposits, due to fluviatile action, are younger than those of marine origin. There are also associated freshwater limestones, as at Geelong, etc. These ancient river-deposits comprise many of the deep leads of the colony, which, as followed downward to the sea, merge into widespread marine deposits. Many of these gravels, as at Ballarat and other localities, are covered with layers of volcanic rock. Those covered by newer sedimentary accumulations comprise the leads of the Chiltern, Huntly and Dunolly, and in the alpine or subalpine areas are represented by terrace-deposits, now worked for the gold which they contain. Some of the beds containing infusorial earth (diaetomaceæ) are lacustrine, as are also some of the Latrobe valley brown-coal beds.

The fossils comprize:—*Diprotodon, Phascolomys, Macropus, Procoptodon, Nototherium, Dasyurus, Thylacoleo, Hypsiprymnus, Canis* (this list includes extinct kangaroos, wombat, native bears, dog, wolf-like creatures, etc.); *Arctocephalus, Physetodon*. The prevailing genera of mollusca are:—*Trigonia, Haliotis, Cerithium, Waldheimia, Ditrupa, Lepralia, Tellina, Nucula* and numerous others. The plants include *Eucalyptus, Spondylostrobus, Phymatocaryon, Trematocaryon, Plesiocapparis, Rhytidotheca, Odontocaryon, Celyphina, Conthotheca, Penteune, Platycoila* and *Dieune*.

Economic (Auriferous Leads).

In the Pliocene drifts, are included the principal auriferous

washes of the gold-fields, including the leads of the Loddon valley, as at Talbot, Maryborough, Timor, Burnt creek, Dunolly, Waanyarra, Kingower, Inglewood. Also the Avoca valley, including Amphitheatre, Avoca, Homebush, Moonambel, Stuart Mill, St. Arnaud, etc. At Ararat, Stawell, Balmoral, Ballarat, Buninyong, Smythesdale, Pitfield Plains, Blackwood, Heathcote, Malmsbury, Taradale, Rutherglen, Rushworth, Upper Goulburn valley, Beechworth, Ovens valley, Kiewa valley, Mitta Mitta, Omeo, Limestone creek, Dargo valley, Mitchell valley, Wangaratta, Wongungarra, Tambo valley, Bendock, Delegate river, Combinbar creek, Nicholson valley, Wentworth, Tanjil, Thompson river and tributaries, etc.

Brown Coal.

Enormous beds of brown coal have been proved by boring near Morwell, Boolara, Yarragon, near Morwell river junction, and other localities in the Latrobe valley. At Morwell, some of the beds are 276 feet thick, separated by beds of clay and sand. In one place the aggregate thickness of such beds amounts to over 700 feet.

Detrital Gold.

Mr. Murray observes that the principal modes in which detrital gold occurs are as follows:—

(1) In surface-soil and rubble resting immediately on Silurian rocks; (2) in angular or waterworn detritus in the beds of gullies, flats and depressions, or on slopes adjacent to them; (3) in the gravels in the beds, or on the banks, of creeks and rivers; (4) in widely-spread gravels and conglomerates capping hills and spurs of Silurian rock, sometimes overlain by basalt; and (5) in the gravels of leads or ancient river-channels eroded in the Silurian rocks, and covered either by a succession of sedimentary layers or by one or more sheets of basalt, to thicknesses of sometimes several hundreds of feet.

We see that the particles of gold occur in various forms:—(1) As impalpable dust; (2) as fine scales; (3) fine but solid "specks"; (4) "coarse specks" from a few grains to several pennyweights; and (5) "nuggets" from several pennyweights to many pounds in weight. We further notice in fragments of appreciable size infinite varieties of solidity, form and texture, from the solid, rounded, or oval "shotty" fragment, smoothed and welded by the action of ages of attrition, to the rough, "honeycombed" particle with quartz attached, recently disintegrated and not far removed from its matrix.

There are four classes of mining adventure now in progress:—(1) The search for comparatively shallow alluvial deposits; (2) the search for deep auriferous leads or "alluvial" deposits between the widely-spread layers of basalt or coverings of post-Tertiary sedimentary origin; (3) the search for auriferous quartz-reefs in country where the Silurian bed-rock is at or near the surface; and (4) the search for quartz-reefs in the Silurian bed-rock beneath the deep "alluvial" deposits.

In all three pursuits, we possess useful guides in our knowledge of the areas of exposed Silurian country, in which the shallow ground has been proved auriferous, in the facilities afforded there for ascertaining the general bearing of strike of the Silurian rocks, and in the knowledge of the fact that gold-bearing country occurs in belts of greater or less width, which correspond with that strike in longitudinal direction. From such facts as these, certain deductions were made as to the auriferous continuity of the lead system, as follows :—

If the general trend of a deep lead is on the prolongation of the strike of the Silurian rocks in a strip of shallow auriferous country, we may expect that lead to continue auriferous for a long distance, as the probability is that the quartz-reefs continue auriferous in the subjacent bed-rock, or that their denuded portions on that course contained gold, and furnished supplies of the metal all along such course during the denudation of past ages.

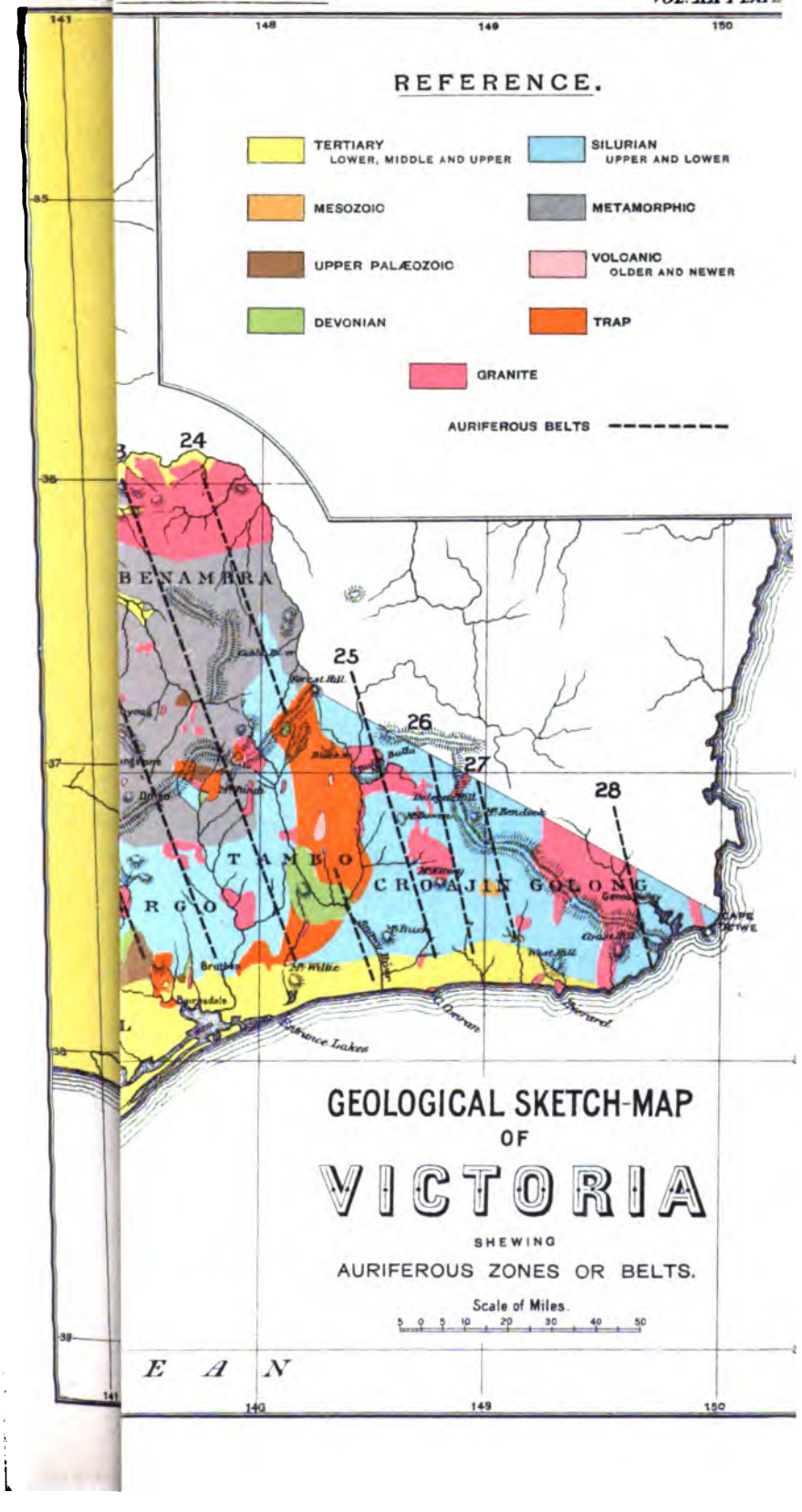
It does not necessarily follow that an auriferous belt will be found to maintain its character indefinitely, as traced along its course, and there are always poor or barren portions even in the richest belts, as there are occasional occurrences of gold in strips of country of generally non-auriferous character ; but the evidences are all in favour of the belief that once a certain set of strata is found to contain auriferous veins in any particular portion of its course, other "makes" of gold-bearing quartz are likely to be found in following that course.

Whatever local exceptions may occur, it may be advanced as a general rule for the guidance of investors that deep leads, on or near the extensions, in the normal north-north-west to north-north-east strike of the exposed rocks of the proved auriferous-zones, are those most likely to reward outlay in testing them. Such a position augurs far more favourably for success than the circumstance that deep ground to be tested is the continuation of some particular lead.

Taking the case of a lead system trending across instead of with the strike of the Silurian rocks, we have as an example that running westerly from Ballarat toward Burrumbeet. This is sure to cross alternate auriferous and non-auriferous belts of Silurian rocks, and we may expect the character of the gravels to vary accordingly ; it is possible, indeed, that the denuding and transporting agencies in past times were sufficiently powerful to convey much gold from the auriferous belts over the adjacent poor or barren ones.

Thus, for instance, the general trend of the extension of the Kingston and Smeaton leads is for many miles on the prolongation of the great auriferous belt which extends from Buninyong through Ballarat and Creswick, and we can be certain that the quartz-reefs of that belt, at any rate so far as their denuded portions were concerned, maintained their auriferous character as far as the Kingston leads have yet been worked, and on tracing out the northern prolongation of the belt to exposed Silurian country we find that the gold-fields of Tarnagulla and Inglewood are on that course. It may therefore justifiably be inferred that the subjacent bed-rock of the valley from Kingston to Newbridge is traversed by lines of quartz-reefs which are—or the denuded portions of which were—auriferous at intervals, and so enabled the supply of gold to the detrital deposits to be kept up.

As before remarked, the valley of the Loddon and its branches presents indications of having been the scene of very extensive denudation, and all detrital deposits beneath the basalt of that valley must be the residue from the disintegration of a vast amount of material. The basalt of the plains from Kingston northward covers a lead system composed of a trunk lead and numerous large tributaries, besides a system of low Silurian ranges intersected by gullies, with probably many cappings of drift, "reef-washes," and gravels, other than those of the leads proper.



GEOLOGICAL SKETCH-MAP
OF
VICTORIA
SHEWING
AURIFEROUS ZONES OR BELTS.

On the line of country from Creswick and Kingston, towards Tarnagulla, it is likely that not only the deep leads themselves, but comparatively shallow alluvial deposits resting on the bed-rock will be found remunerative. In this, as in the case of any other similar lead system running with the strike of the Silurian rocks on the course of a known auriferous belt, whatever local failures may be encountered we may confidently expect the continuity of the auriferous character of the gravels while that general course is maintained.

Conclusion.

From a careful consideration of the evidence available, the writer is led to conclude that the principal auriferous quartz-veins now being worked in Victoria were formed in post-Silurian, and probably in pre-Jurassic times, the greatest number during the Lower Devonian period of volcanic activity.

Also that we may consider the auriferous veins under three classes:—

(1) Lodes formed at or near the contact with granitic intrusions, as at Dargo, Stawell, Maldon, Beechworth, etc.

(2) Lodes formed in association with eruptive dykes, as at Walhalla, Woods Point, Tanjil, Omeo (Dry Gully), Cassilis, etc.

(3) Lodes not directly associated with dykes, in only partly altered or unaltered Silurian rocks, as at Ballarat, Bendigo, Castlemaine, etc.

That notwithstanding the extensive volcanic outbursts of Tertiary times in Victoria, and the possibility of metallic solutions accompanying the upwelling lavas, and also the fact that precipitation of metallic solutions is still in progress in certain cases, no payable quartz-reefs or auriferous matrices other than the alluvial deposits, are of Tertiary origin in Victoria, except cases of secondary pyrites, coating the joints and filling fissures in the quartz of lodes.

The Chairman (Mr. H. C. Peake) moved a vote of thanks to Mr. Stirling for his interesting paper, and for the interesting display of photographic views of the colony of Victoria. These views illustrated the difficulties which were overcome by mining-engineers in all newly settled countries.

Mr. J. S. Martin (H.M. Inspector of Mines) seconded the resolution, which was cordially approved.

Mr. W. K. Laurence's paper on the "Saltford Slip" was read as follows:—

SALTFORD SLIP.

By W. K. LAURENCE, M.Inst.C.E.

On February 27th, 1900, at about 6·40 p.m., a heavy landslip took place on the south side of the Great Western railway adjoining the eastern end of Saltford tunnel, between Bristol and Bath, some 10,000 tons of material from the side of the cutting at this point moving forward about 14 feet, completely blocking the down main-line. The accident that followed was fully reported in the newspapers at the time; fortunately no lives were lost, and no personal injuries were sustained. The slip took place without the slightest warning, the ganger of the length having examined the cutting throughout immediately before the occurrence.

Saltford cutting, with slopes of 1 in 1, is of an average depth of 55 feet, and in the upper half the material consists of a yellow clay intersected by beds of white Lias limestone, the lower half being of blue clay with beds of blue Lias limestone. The beds incline about 1 in 48 to the north or railway side, and for about ¼ mile in this direction the surface of the ground falls sharply down to the river Avon.

It may naturally be asked what could have been the cause of the slip, as a period of some 60 years had elapsed since the open cutting was made. After carefully considering this question the writer can only suppose that a very slow and gradual percolation of water took place into the open cutting on the upper surface of an inclined bed of blue Lias limestone, situated at about rail-level or 50 feet from the surface of the ground, and that the cohesion of the various strata on either side of the area percolated by water was at last insufficient to withhold any longer the mass of ground from sliding forward. No doubt, the long-continued wet weather during February, 1900, and the vibration of the ground caused by passing trains aided the movement.

On excavating the slip, a smooth greasy surface was found on the bed of blue Lias limestone above referred to.

The CHAIRMAN (Mr. H. C. Peake) moved a vote of thanks to Mr. Laurence for his paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Mr. T. MORGANS' "Notes on the Lead-industry of the Mendip Hills" was read as follows:—

NOTES ON THE LEAD-INDUSTRY OF THE MENDIP HILLS.

By THOMAS MORGANS, M.Inst.C.E.

Historical investigators have shewn that the plumbiferous deposits of the Mendip Hills were worked by the ancient Britons and immigrant Belgians before the Roman invasion.

The very large accumulations of débris, lead-ore slimes and lead-slags, among which and contiguous to which have been found Roman coins, pottery, ornaments, tools, pigs of lead, graves, etc., sufficiently attest the extensive character of the Roman lead-mining, ore-dressing and smelting operations on these hills. Vestiges of a Roman camp exist near Charterhouse lead-débris deposits.

Collections of Roman remains found on the Mendips exist in museums in Bristol and other places, and in private hands. More than forty pigs of Roman lead have been found in Great Britain. One was found at Charterhouse lead-works in 1876. These works are situate about 4 miles north-west of St. Cuthbert's lead-works, which are to be inspected by the members of the Institution of Mining Engineers.

There are two Roman pigs of lead in the Bristol Museum. One of them has on its bottom the Emperor Vespasian's name in relief letters, and is assumed to have been cast in A.D. 70: this pig weighs 182 pounds. The other, which weighs only 89 pounds, has in relief on its bottom the name of the Emperor Antoninus Pius, and dates between A.D. 138 and 161. These pigs are similar in form—a truncated pyramid having a rectangular base. The Vespasian pig is a very neat casting. Lines of stratification are conspicuous along its sides, pointing to successive additions of molten metal to that already chilled in the mould. The moulds used were presumably of stone or dried clay or loam. Some Roman pigs of lead exhibit the letters EX. ARG. Dr. John Percy, the metallurgist, was of opinion that these letters "clearly mean EX ARGENTO, free of silver or desilverized."* Recently a slab of

* *The Metallurgy of Lead*, 1870, page 214.

litharge from 1½ to 2 inches thick was found in the débris at the St. Cuthbert's lead-works. This litharge may possess some significance, in connection with the desilverization of lead by the Romans. Three small ingots of Roman silver have been found in England and Ireland.

From the beginning of the seventeenth century up to about 1870, operations in mining on a more or less extensive scale were conducted on the Mendips. Part of this mining was for lead and part for zinc-ores. The treatment of the Roman slags for recovery of lead from them was begun in the thirties or forties of the present century, and later a beneficiation of the Roman tailings and slimes was attempted and carried on with some success while lead stood at a good price. Three or four separate firms erected dressing and smelting-plants and at Charterhouse lead-works a small Pattinson plant for desilverizing was erected.

The following description by Mr. Joseph Glanvil of mining and smelting operations on the Mendips, as carried on in the seventeenth century, appeared in 1668:—*

There is *Sparr* and *Caulk* about the Ore; and another substance, which they call the *Crootes*, which is a mealy white stone, marked with Ore, and soft. The *Sparr* is white, transparent, and britle like glass. The *Caulk*, white and heavy, heavier than any stone. The *Vein* lies between the Coats, and is of different breadths. It breaks off sometimes abruptly in an Earth, they call a *Deading Bed*, and after a fathom or two may come again, keeping the same point. It terminates sometimes in a dead Earth Clayie, without *Croot* or *Sparr*; sometimes in a Rock called a *Fore-stone*.

There is much difference in the goodness of the Ore. The cleerest and heaviest, best. 36 hundred of Ore may yield a Tun of Lead. Some small eyes of other mixtures, Brass, &c.

They beat the Ore with an Iron flat piece; cleanse it in Water from the dirt; sift it through a Wire-sive. The Ore tends to the bottom, and the Refuse lies at top. And these are the Preparations, they make use of, before 'tis fit for fusion. Then they have a Hearth about 5 foot high, set upon Timber, to be turn'd as a Wind-mill, to avoid the inconvenience of smoak upon a shifting Wind. The Hearth contains half a bushel of Ore and Coal, with bellowes on the top. The Charcoale is put upon the Hearth, where the Ore is; laying dry Gads upon the top, which they call their White coales. There is a sink upon the side of the Hearth, into which the Lead runs, that holds about an hundred and an half. Then it is cast into Sand, and runs into those *Sowes* (as they call them) which they sell. They have a barr, to stir the Fire; a Shovel, to throw it up; and a Ladle heated red-hot, to cast out the Mettal.

* *Philosophical Transactions of the Royal Society*, 1668, vol. iii., number 39, page 770; reprinted in *The Metallurgy of Lead*, by Dr. John Percy, 1870, page 537.

Once melting is enough. The good melts best, and the best, first. There is sometimes half odds in the goodness. The best is distinguisht by its weight.

There is a *flight* in the smoak, which falling upon the Grass, poysons those Cattel that eat of it. They find the taste of it upon their lips to be sweet, when the smoak chances to fly in their Faces. Brought home, and laid in their houses, it kills Rats and Mice. If this flight mix with the Water, in which the Oar is wash't, and be carried away into a streame, it hath poisoned such Cattel, as have drunk of it after a current of 3 Miles. What of this *flight* falls upon the sand, they gather up to melt in a Slagg-hearth, and make Shot and Sheet-lead of it.

They sometimes find *Slaggs*, 3, 4, or 5 foot under ground, but such as they judge cast aside heretofore.

There is much of interest in the foregoing narrative. The ore being sought is not named. It was probably galena. Of its accompaniments, *sparr*, *caulk* and *crootes*, it is not determinable whether the *sparr* was quartz or calcite, but it was probably the latter. The *caulk* (cawk) was probably barytes or heavy spar. *Croot* cannot be determined from the reference to it. Very little barytes is now found in this district, but celestine (strontium sulphate) is abundant.

Clearly the ore was found in a vein of varying breadth lying between *coats* (otherwise "walls"). This was probably one of the many gash-veins, mostly nearly vertical, that are found in the Carboniferous Limestone which is exposed over so large a proportion of the Mendip range. Most of these veins have clay as gangue—there generally being much clay and little ore. The *deading bed** of the above description might have been an intrusion of material different from the ordinary gangue of the vein and without ore-impregnations. Such changes might occur when the fissure passes from the Carboniferous Limestone into the Lower Carboniferous Shales, or from the latter into the Old Red Sandstone, which, with the shales, is exposed on the Mendips. The *fore-stone* might have been a cross-course of some hard ground. Dykes of intrusive material do not appear to be known in the Mendips, but trap-rock has been exposed by denudation at several points. It is assumed that igneous material forms the core of the Mendip range.

The yield of lead from the ore seems to have been about 55½ per cent. If the ore was galena, and was generally well cleaned in the manner described, this yield points to a heavy loss in fume

* The terms "deading" and "deading work" in use in the collieries in the Bristol coal-field refer to unproductive work such as driving through faults, driving cross-measure headings or branches, etc.

and slags. More information concerning the "hearth about 5 foot high, set upon timber, to be turn'd as a wind-mill" and some about its tuyère would have been interesting. Possibly it was a hood, not the hearth itself, that was revolved to suit a shifting wind. Turning the hearth would have disarranged the tuyère-connections with the bellows, unless the latter was also shifted around as much as necessary. The *gads* or *white coales* laid on top of the hearth were pieces of dried wood. Charcoal was contradistinctively called "black coals." The effect of lead-fumes or "*flight* in the smoak" upon the higher grades of animal life is graphically described. So long as two and a half centuries ago, and no doubt earlier than that, the pastoral and lead-producing interests in this country were in antagonism. It is not quite clear whether the manufacture of shot and sheet-lead from the lead resulting from treatment of the fume in a *slagg-hearth* was carried on on the Mendip Hills or elsewhere. Sheets of lead, 20 feet long by 5 feet wide, and of any desired thickness, used to be cast in this country. Dr. Percy states that he saw such sheets being cast during his boyhood; also that rolling or "milling" lead into sheets appears to have been first practised in this country in 1670; further, that the Chinese prepare their thin tea-lead by pouring a suitable quantity of molten lead upon a smooth stone, and then promptly lowering a heavy smooth-faced stone upon the fluid metal.

Smelting-operations, as conducted at St. Cuthbert's lead-works between 30 and 40 years ago, were well described by Mr. H. Curwen Salmon in the *Mining and Smelting Magazine* in 1864. At that date, three separate firms were conducting smelting-operations on the Mendips with one furnace each. One of those smelting-furnaces was working at St. Cuthbert's, where, at that date, five more were in course of erection to deal with an estimated quantity of 500,000 cubic yards of lead-débris and slimes then lying on 25 acres of land belonging to the Ecclesiastical Commissioners, which land adjoined or was near the St. Cuthbert's works. Each cubic yard was estimated to contain £1 worth of lead—the value of the lead in sight being thus £500,000. Lead was then worth about £21 per ton in the market. A cubic yard of the débris was estimated to weigh nearly 30 cwts. and to contain from 5 to 10 per cent. of metallic lead in ore form—equal to

from 1½ to 3 cwts. of metallic lead per cubic yard. Already this deposit, with others in the district, had been worked over some years earlier by Dr. Somers, to some depth, to extract the Roman grey slags. These he had smelted with pecuniary advantage. The black slag resulting from his treatment of the grey slag contained, it was said, 5 per cent. of lead. No analyses of these grey and black slags appear to have been published, consequently the character of the fluxing cannot be determined. Limestone, iron-ore and scrap iron are understood to have been charged with the grey slag to the reducing furnace.

Subsequently to 1850, the material smelted consisted of a mixture of débris and slime-concentrates, lead-fume or flue-dust, such grey slags as had been left in the débris by Dr. Somers' workpeople, and some of his black slag. The market value of the lead in a ton of the latter was about £1, and it was alleged that it could be extracted with profit by resmelting. That was a doubtful matter, because probably not less than one-fourth of the lead in the black slag was lost in fume and residual slag by the method pursued. But this slag was, doubtless, of value in the charge, both for keeping it open and giving a lead to its fusion.

The concentrates were prepared by means of buddles of rather small diameter of bed. These effected rather poor dressing, which was in part accounted for by the alleged large proportion of float-lead existing in the slimes, that could not be settled and captured by buddles. The débris and slimes were dressed up to a lead-content of 40 to 45 per cent., equivalent to between 51½ and 58 per cent. of lead carbonate, in which form the lead was said chiefly to exist. A little of the lead might have been in the form of fine galena or fine sulphate. The balance of 40 per cent. and more is supposed to have consisted mainly of silica in sand form. The specific gravity of the latter is only from 2·2 to 2·6, while lead carbonate (cerussite) is 6·46 to 6·48, sulphate (anglesite) is 6·3, and sulphide (galena) is 7·4 to 7·6. With so wide a difference between the specific gravities of sand and ore, it is clear that the latter must be in a state of very fine division and in float condition to escape capture in dressing while the former gets settled on the beds.

The state of fine division of the concentrates rendered them unfit for being charged to the smelting-furnace. They were first heated to a pasty condition and agglomerated into lumps on the

bed of a reverberatory furnace called a roaster. If any carbonic acid was liberated from the ore during this operation the proportion of lead in the remaining concentrate would be increased.

The lead-fume from the furnace was condensed and precipitated; and the ore and fuel-dust, mechanically carried with the furnace-gases, were collected in flues, of which there was a length of 2,400 feet. The flue-soot contained from 50 to 60 per cent. of metallic lead—being 10 per cent. richer at the beginning of the flue-course than at the chimney-end. It was, like the concentrates, agglomerated in the roaster before being charged to the smelting-furnace. The Roman grey slags were said to vary very much in lead-content. Some were rich and contained metallic lead: probably they carried a mean of 30 to 40 per cent. of metal, as sulphate, etc. The concentrates, flue-dust and grey slags formed a tolerably rich lead-mixture for charging to the smelting-furnace. It was diluted by the addition of black slag and a small proportion of limestone and iron-ore for fluxing. There was a very low column of material above the tuyères in the furnace; consequently a large proportion of the lead-content, seemingly more than half of it, was volatilized by the furnace and collected (in part) by the flues to be re-furnaced and (in part) re-volatilized in successive operations. Probably not less than 10 per cent. of the lead charged to the furnace regularly escaped to the atmosphere through the flues. It is said that about 12 tons of dressed material, averaging 45 per cent. of lead, could be treated in the smelting-furnace per 12 hours shift. The furnace worked 11 consecutive shifts per week and was raked out on Saturday afternoons, when masses of ferruginous matter were usually got out. A fan-blast of barely ½ pound per square inch pressure was used.

It was found that dressing operations could not be carried on extensively enough to deal within a reasonable time with the large quantity of débris and slimes available. During a half-year's run in 1864, the blast-furnace produced 130·3 tons of pig-lead. It was estimated that 16 tons of crude débris, dressed up to 45 per cent., or more, of lead-content, was used for the production of 1 ton of pig-lead—the half-year's consumption of raw material having been consequently about 2,085 tons. Thus, a single furnace of the type and size then in vogue used up no more than say 4,200 tons of débris per annum, which was but a small fraction of the 500,000 tons available. The cost of producing the 130·3 tons of lead was

£1,602, which amounted to 15s. 4½d. per ton of débris consumed, and to £12 6s. per ton of lead produced. Of the latter amount, £6 6s. was allocated to the cost of digging, transporting (including steam-power for inclined-plane to dressing-floor) and dressing the 16 tons of débris (being 7s. 10½d. per ton), £5 to smelting (being 6s. 3d. per ton of débris) and the remaining £1 to agency-charges (being 1s. 3d. per ton of débris). The value at the works of the lead produced during the same half-year was £2,466, being a mean of £18 18s. 6d. per ton, and the profit was £864, which was equal to 8s. 3d. per ton of débris, and to £6 12s. 6d. per ton of lead. The mean market quotations for pig-lead during the same half-year were £22 12s. for W.B. and £21 16s. for good brands. During the best three consecutive months of the said half-year, 71 tons of soft pig-lead were produced. On this quarter-year's output the £5 smelting cost per ton of lead was allocated as follows:—

	Tons.	Cwts.	Qrs.	Lbs.		s.	d.	£	s.	d.
Coke for blast-furnace	2	0	0	0	at	14	6	1	9	0
Coal for agglomerating, and lead-softening or improving furnaces	0	13	1	0	,,	12	10	0	8	6
Coal for fan-engine	1	1	1	14*	,,	,,		0	16	3
Labour at furnaces, including two-thirds of wages of engine-men	...	...	...	...		...		1	19	5
Wear and tear, and sundries	...	...	...	...		...		0	6	10
								5	0	0

* This weight should be 1 ton 5 cwt. 1 qr. 0 lb., or the price should be 15s. 3d. per ton.

Though the water, then available, was not sufficient for concentrating-works on a much larger scale, it was necessary to considerably extend the operations in view of the magnitude of the capital. At last it was decided to smelt the débris and slimes undressed as dug, except that the free water in the material was first to be evaporated by a suitable drying method, and excepting occasional portions of the deposit that contained a large proportion of broken sandstone—such portions having to be dressed to separate the stone.

An experiment in smelting about 200 tons of crude débris was made in the old furnace. From 7 to 8 tons of it was passed through the furnace per 12 hours shift with a consumption of from 20 to 30 cwts. of coke. The blast-pressure was a little under ½ pound per square inch. Three-fourths of the lead-content of the charge was volatilized, and it was assumed that nearly all of this fume was collected in the flues. The final yield of pig-lead

was estimated to be about 6½ per cent. of the weight of the débris treated. The lead contained 3 ounces of silver to the ton. The estimated profit was very satisfactory (the cost being reduced to £9 9s. 6d. per ton of lead produced), although the loss of lead and silver by this method must have been enormous. This method of volatilization resembles the first stage of the Lewis-Bartlett process for making "sublimed white-lead" for paints, which is being successfully carried on in one or two localities in the United States of America.

It is not at all unlikely that the raw lead-material charged to the furnace during the experiment at the St. Cuthbert's works contained as much as 10 per cent. of lead. Some fluxing-material, consisting of limestone and iron-ore, was added, but the proportions of fluxes used were kept more or less private. As undoubtedly the raw material varied in composition, and as no chemist appears to have been employed at the works, it is more than probable that the resultant slags were of varied constitution and degree of cleanness. It was claimed that they did not contain more than 1 per cent. of lead. Inclusive of the flux, the mean lead-content of the charge was, doubtless, not below 9 or 8 per cent. Charges of this proportion of lead are successfully treated in the United States of America in blast-furnaces of rectangular horizontal section, having an internal area of 35 to 40 square feet at the tuyère-level, and treating 50 tons of ore and flux per 12 hours shift—the column of materials varying from 10 to 15 feet in height above the tuyères, and the loss of lead is said not to exceed 10 per cent.

The scheme, for which the erection of five new blast-furnaces was begun in 1864, contemplated the sublimation and transfer to the flues of three-fourths of the lead-content of the crude débris charged to the furnaces. A patented apparatus (apparently on a rather small scale) was laid down for drawing the furnace-gases through the flues and for washing them with water so as to deprive them of all lead-material before dismissal to the atmosphere. The furnaces were circular in horizontal section, and 4¼ feet in diameter (14·19 square feet in area) at the tuyère-level. The margin of the dished bottom was 9 inches below, and the sill of the charging-door (which was at the back of the furnace) only 15 inches above the tuyère-level. There were two water-tuyères, with nozzles 1¾ inches in diameter, placed at the back of the furnace and

pointing to its centre at an angle of about 90 degrees apart. The blast-pressure was to be 2½ pounds per square inch,* and the top of the charge was to be kept at no more than 18 inches above the top of the tuyères. It was expected that each of these furnaces would work off from 100 to 130 tons of crude lead-débris per week, and yield in the same time from 1½ to 2 tons of pig-lead and from 8 to 12 tons of flue-soot containing a mean of about 55 per cent. of metallic lead. The pecuniary results accruing from treating the débris by the method and with the five furnaces and condensing-plant described above were not satisfactory. The conditions were:—very cheap lead-material in the crude condition, cheap fluxes, expensive fuel for blast-furnaces and blowing-engine, and appreciable cost of carriage of the lead to market.

Recently a concentrating and smelting-plant of the most modern description has been erected at the St. Cuthbert's lead-works. The concentrating-plant consists of revolving barrels for disintegrating or pulping the crude material, a picking-belt for the rough material from the barrels, classifiers for the pulped or float-material from the barrels, jiggers, Wilfley tables and a Frue vanner. The tailings and slimes in suspension are precipitated from the water during slow progression of the latter through settling-ponds, and the clarified water is used over again. A water-jacketed blast-furnace, circular in horizontal section, has recently been completed for smelting the concentrates which are to be briquetted by machinery, the erection of which is nearly, if not quite, completed. The plant will be described and the sequence of events in the concentrating process, etc., will be explained to the members of The Institution of Mining Engineers by either Mr. Jenks or one of his co-directors.

Sections, several feet deep, of the débris and slimes as left by the Romans will be seen, as well as some of their grey slags. Stratification is visible in the tailings-deposits, which no doubt represents variations in the ores and their matrices crushed and dressed. Some tailings from modern concentrating-operations have been deposited upon the ancient tailings. The surface-line of the latter is frequently well marked by bits of Roman charcoal, which having been cast with the grey slags into the tailings

* The blast injected would be equivalent to the consumption of about 4 hundredweights of coke per hour.

settling-ponds, floated off on the surface of the water, and so formed a top stratum when the ponds dried up. Upon this stratum, the tailings from dressing operations, conducted since the middle of the present century, were settled.

No extensive amount of water is available on the Mendips for ore-dressing and other purposes. Some of the regular supply is said to issue from the Lower Carboniferous Limestone Shales.

Old Red Sandstone underlies the sod close to the St. Cuthbert's leadworks and continues to be the surface-rock for some distance to the east. Carboniferous Limestone occupies an extensive area of the surface in the neighbourhood of the works. There is a patch of Dolomitic Conglomerate (which is a member of the Trias) near the works, and there are several other tracts of it within 5 or 6 miles. The road, 3½ to 4 miles long, from St. Cuthbert's to Wells, descends a vertical depth of about 800 feet, and crosses exposures of Old Red Sandstone, Lower Limestone Shales and Carboniferous Limestone, Dolomitic Conglomerate, Keuper Marls and Lower Lias Clays. This part of the Mendips appears in sheet No. 19 of the Geological Survey Maps on the scale of 1 mile to the inch.

The geological formation from which the Romans obtained their lead-ores is a matter of interest. It may be questioned whether the ores were obtained exclusively or even largely from the Carboniferous Limestone, as is often assumed. In an oft-quoted translation from Pliny's *Natural History* it is explicitly stated that while the Romans more laboriously dug up lead-ores in Spain and Gaul, they found them in Britain so abundantly in the upper crust of the earth that a law was established forbidding the making of more than a stipulated quantity of lead from British ores.

This points to the working, generally, of surface-deposits in Britain, and doubtless applied to Roman mining in Yorkshire and Derbyshire as well as in Somerset. No ancient workings resembling adits, headings, sinkings or rises have been found in solid rock in the Mendips. Roman appliances were hardly equal to driving in hard rock except on a small scale. Rending by means of fire would have been their easiest course. Beds of lead-ore in, and conformable with the bedding of, the Carboniferous Limestone, with such ore-beds at different horizons in the bedding and perhaps connected by leaders traversing joints in the limestone

perpendicular to the bedding-planes, are not known in the Mendips, but sporadic strings and small nests of galena occasionally occur. It is of course possible that any substantial lead-veins or bodies that existed in the limestone were entirely worked out by the Romans, though of such workings there is little or no evidence. No traces strongly indicative of ore-mining appear to have been found in any of the caves.

Several more or less vertical veins of clay traverse the Carboniferous Limestone, and possibly the Old Red Sandstone. In the limestone some of these veins run in tolerably straight lines for considerable distances. How the gashes enclosing the veins were formed has not been settled. Some of them may have been tension-ruptures occasioned by the elevation of the Mendips, but without throw in the plane of the gash; while others may be lines of fault in which one of the walls has moved differently from the other in direction and extent in the plane of the fracture. About 270 feet is believed to be the greatest depth to which any of these clay-veins has been explored in modern times. That was a sinking in search of lead-ore; no rock-bottom was reached, nor was sufficient ore of any sort found to justify further exploration. The writer has been informed that in the limestone at Dolebury Warren (situate about 7 miles north-west of St. Cuthbert's lead-works) two parallel gashes, several feet apart and both filled with clay, had been bottomed at depths of 30 to 40 feet, and that in both cases the bottom was concave transversely in solid limestone. This suggests that these two gashes were ancient water-courses and that they had possibly been entirely excavated by water. The clay forming most of these veins is mineralized in places. Galena, manganese, iron oxide, ochres, quartz, and, of course, calcite are met with. The quantity of any kind of ore met with at any place during the late years has not sufficed to keep more than a very few men employed. The galena is often found in the clay in small lumps that are columnar, with occasional films of extraneous matter between the columns. It is a common saying among workmen that pieces of ore of this kind have "grown" upwards from a piece of stone upon which they, it is said, usually sit, and with which their bottom surface conforms. Consequent from their form these examples are sometimes called stalactitic, but rather are they stalagmitic if they accrete in the way which the workmen believe.

If the Romans excavated in these clay-veins for lead-ores they no doubt re-filled them with the waste clay, etc. The writer has seen in one clay-vein a couple of pits of small diameter lined with dry-stone walling. It is probably not justifiable to assume that these are of Roman construction. Bits of wood and broken pottery have been found in some clay-veins at depths of a few feet below the surface.

The origin of the clay occupying the gashes is matter of interest. As a chance speculation it might be conceived that it is decomposed dyke-material derived from the igneous core of the Mendips. It was, however, shewn in 1864 and later by Mr. Charles Moore that most of the clay-veins in these hills consist of material of Rhætic, Liassic or Oolitic age. Clay obtained from a depth of 270 feet in a vein in Carboniferous Limestone at Charterhouse contained Liassic remains in abundance. Three cartloads of deposit from within a fissure in corresponding limestone near Frome yielded approximately a million specimens of fossils of Rhætic age, 70,000 of these being teeth of a single fish species, the *Lophodus*. A large proportion of this particular find of fossils may be seen in the Museum at Bath. Mr. Moore was of opinion that the limestone-fissures were filled with clay during submergence in Jurassic seas. Others are of opinion that the fissures were developed by earth-movements at later periods, and that the filling occurred in Tertiary or Glacial times.

It is not improbable that the Romans obtained lead-ores from the Dolomitic Conglomerate. This deposit, which rarely exceeds 30 feet in thickness, is well known in the west of England. It was and is in several places in Somerset and Gloucestershire highly charged with various useful minerals. Magnesia is not a constant constituent of this Conglomerate, and consequently portions of it in some parts of the west of England are not dolomitic. Because of its frequent dolomitic character, it has been regarded by some as the equivalent of the Permian formation developed in the central and northern parts of England; but it has been demonstrated that the Dolomitic Conglomerate really is a member of the Trias, and appeared no earlier than the Keuper, in which it occurs at all altitudes. The Permian fossils are Palæozoic; the Conglomerate fossils are Mesozoic. The Conglomerate is a coastal formation, and consists mostly of limestone-shingle and boulders cemented together by carbonate of lime, with, frequently, carbo-

nate of magnesia, and, occasionally, oxide of iron in admixture. On the Mendips and their flanks, it occurs in denuded areas at varying altitudes. In a few instances on the hills, it passes under Lower Lias Clays, and on their flanks it mostly passes under Keuper Marls. Iron oxides (red, brown, ruddle, and yellow and brown ochres), manganese oxides, lead and zinc sulphides (galena and blende), barium and strontium sulphates (barytes and celestine), and zinc carbonate (calamine), occur in this Conglomerate. Generally, one kind of ore prevails in one locality, and another in another. The carbonate of zinc which was so extensively worked at Rowberrow, Shipham and Harptree in the Conglomerate during portions of the last and present centuries (and was sent to Bristol, Keynsham, Birmingham, etc., for the manufacture of calamine-brass—an industry now defunct) was undoubtedly derived from the sulphide, some quantity of which appears to have been occasionally found in the same places. It is but reasonable to suppose that lead sulphide occupying a surface-position in the same Conglomerate formation, and under corresponding atmospheric and hydraulic influences operating through the many ages during which the Conglomerate has been exposed, would be converted into carbonate contemporaneously with the conversion of the zinc sulphide. From this view it is not unreasonable to suppose that the Romans mined, dressed and smelted lead carbonate, and that the finely-divided carbonate now found in their tailings and slimes is material lost during their dressing of carbonate ore. On the other hand, it is the opinion of some that the fine ore (which is almost exclusively carbonate) recovered from the tailings and slimes, has been derived from finely-divided galena that escaped capture during dressing, and became disseminated through the tailings. It is assumed that during the period of 1,500 to 1,800 years, or more, since the fine galena was deposited, it has been first converted into sulphate through oxidation of both lead and sulphur effected by percolation of aerated rain waters, and next through contact of bicarbonate of lime in solution with the sulphate, double decomposition ensued, resulting in sulphate of lime (gypsum, specific gravity 2·3) and carbonate of lead. In such a case, carbonate of lime must have been originally present in the tailings, to provide the bicarbonate for the reaction, and the resultant sulphate of lime should now be found in the tailings. If, however, the reaction was effected by carbonate of magnesia from the Con-

glomerate, the resultant sulphate of magnesia, being soluble, would have disappeared. Small pieces of galena are occasionally found in the tailings. Undoubtedly this description of ore was used on the Mendips by the Romans, but the writer believes it to be more than probable that the carbonate was also used by them.

In addition to treating the deposit of ancient tailings and slimes situate close to the St. Cuthbert's lead-works, the company are operating upon some débris covering the Chewton Warren, which is an area of about 900 acres situate north of the works, and connected therewith by a tramway about ½ mile long. Dolomitic Conglomerate underlies a part, and probably nearly the whole, of this Warren. The surface has been dug over to some feet in depth (probably down to the hard Conglomerate) by the Romans and moderns, but their débris here has not been washed. It contains small fragments of lead-ore which are chiefly carbonate, but with occasional bits of galena. It seems to be more than probable that from this considerable area the Romans removed the upper portion of a nearly horizontal deposit of lead-ore, which the writer submits was probably carbonate, lying upon and embedded in the surface of the Conglomerate. Possibly, the ore was overlain by a slight depth of either decomposed Conglomerate or undenuded Triassic Marl or Liassic material, which now constitutes the bulk of the débris. At one or two points, the company have exposed the underlying Conglomerate and begun testing it for lead-ore by means of shafts. Some lumps of galena have been found. The ground is hard and requires powder.

At present, the lead-working operations conducted at St. Cuthbert's lead-works are the only ones on the Mendip Hills. There seems little doubt that from the middle of the seventeenth century, if not earlier, down to the middle of the nineteenth, mining and smelting operations on a varying scale were almost continuous here. Since 30 or 35 years ago, the three or four separate establishments then going have been closed in succession, owing to the obsolete and extravagant character of the plants, to the technical difficulties in treating the ores, and, later, to the declining price of lead, which touched £9 per ton in 1894. About ten years ago all operations had ceased.

Besides the very extensive deposits of lead-débris and tailings existing in the neighbourhood of St. Cuthbert's lead-works, there

are other considerable deposits occupying more than 1 mile of the length of the valley extending south-westward from Charterhouse lead-works.

From numerous tests that have been made it is estimated that the deposits in general contain from 8 to 10 per cent. of metallic lead in the forms of ore and slag. In the aggregate, an enormous quantity of lead-material is thus in sight on the Mendips.

With lead at £15 and upwards per ton there would seem to be a good prospect of reaping pecuniary advantage from treating these deposits by the best modern methods of concentration and smelting.

No experimental tests of any method of dry, or air-blast, concentration of the dried slimes containing the float-lead appear to have been made. Owing to there being an insufficiency of water for wet concentration on a scale commensurate with the reserves of débris available, it is not impossible that smelting the material after a slight concentration, or a separation of say 20 or 25 per cent. of lead-free material, might be a successful course for obtaining the lead-content. This would be a slight modification of the idea of 1864 of smelting the whole of the material as dug. Probably, the slightly concentrated material would require to be briquetted and air-dried—lime being used as a cement for the briquettes and to serve as flux in the smelting-furnace. As there would be but little volatile material in the furnace-charges there would be, roughly, a ton of slag produced for each ton of débris charged, that is, the slag-weight would equal that of the lead-débris, the fluxes and the ash of the fuel less that of the pig-lead produced and of the carbonic acid from the lead carbonate, moisture and fume volatilized. If this large production of slag could be utilized and disposed of so as to yield a small profit, it would be most satisfactory, and surface-area for stacking it as waste-material would not be required.

Slag-cement has for some time past been successfully made on the Continent from blast-furnace slags produced in making pig-iron. The slag as it runs from the furnace is quenched in water and thereby disintegrated. This process also communicates some condition of the material that appreciates the strength of the set cement. A suitable proportion of slaked lime is added to the slag-sand and well mixed by grinding. Uniform mixing and fine grinding are essential. Such cement has excellent properties and competes with Portland cement, especially when the percentages

of silica, alumina and lime are much alike in both—these being approximately 25, 12 and 60 per cent. respectively in typical Portland cement.

It might be that the lead-slags treated in the same way as the iron-slags above mentioned would yield a serviceable cement. It would be a heavier cement than that from iron-slag—lead-slag being commonly of 3·4 to 3·6, or even higher, specific gravity, and iron-slag of 2·9 to 3·0 specific gravity. Good Portland cement has a specific gravity of 3·13 to 3·2, when freshly ground. In lead-slag, iron protoxide is to a considerable extent substituted for the lime that prevails in iron-slag, and, in consequence, the composition of lead-slag cement would vary more from that of Portland cement. Artificial pavements made from various cement mixtures laid *in situ* as concretes, and artificial paving-stones made from town-refuse destructor-clinker, crushed and mixed with Portland cement and well pressed in moulds, are getting more and more into use. Owing to the hardness of lead-slag, a cement compounded from it should make a good wear-resisting pavement.

It is less than 3 miles in a direct line from the St. Cuthbert's works to the Cheddar Valley railway, and the fall between the two points is 800 feet towards the railway. Transport of material on a moderate scale from the works to the railway by means of one of the aerial wirerope systems should, with such a fall in favour of the load, be cheaply effected. The disintegrated slag could be conveyed to a factory at the railway-side and be there converted into cement, paving- and coping-stones, socket-drain pipes, special bricks, etc., and be loaded, when seasoned, into railway-wagons direct. The fuel for steam, drying, smelting, etc., would be conveyed to St. Cuthbert's as back carriage. Some such scheme as this would provide means for carrying on operations on a much more extensive scale than can now be compassed. With a means of cheap transport it might, indeed, become a question whether it would not be most profitable to convey to the railway-side, the more or less concentrated lead débris and to smelt it, and treat its slag-product, there. The latter if untreated could then at least be disposed of for railway-ballasting.

Mr. A. Strahan (London) wrote that the interesting history of lead-mining in the Mendip hills given in Mr. Morgans' paper recalled observations which he made some years ago in Derbyshire

and Flintshire, and recorded in the Memoirs of the Geological Survey. In Derbyshire, the ore was taken to the tops of the hills to be smelted; it was placed in gutters dug out of the ground and opening in such a direction as to catch the prevailing winds; the revolving hearth was a distinct advance on that primitive method.

Caulk or cawk is commonly used as a term for barytes; and coke is the local name in Flintshire for calamine. For many years, the value of this ore was not recognized, and it may not have been distinguished in the Mendips. On the other hand, if its value was known it probably had some name, and it seems possible that *croot* may have been the carbonate of either zinc or lead.

With regard to the source of the ore worked by the early miners, there is no doubt that there were originally rich deposits in sight on the tops of some of the gash-veins, but there were probably also gravel-ores, or lumps of ore scattered through the soil in the neighbourhood of lodes. Large quantities of ore have been raised from the gravels in North Wales both by the early miners and of late years. The small amount of galena which had been raised in South Wales occurred partly in the Carboniferous Limestone, but partly also in the Dolomitic Conglomerate, through which it was scattered, as described by Mr. Morgans. The Liassic limestones also commonly contain specks of galena. The decomposition of the Conglomerate would leave a residue composed largely of small lumps of galena, and this may have been the origin of the deposit on Chewton Warren. The fact that the ore occurs as carbonate points to long-continued weathering.

In North Wales, the galena occurs in the Carboniferous Limestone and in the chert-beds above it. Its distribution seems to be closely connected with certain zones in the limestone, but especially to have been determined by the occurrence of beds of shale. The comparative scarcity of shale-beds in the Mendip area may account for the irregularity of the ore-deposits.

The PRESIDENT (Mr. H. C. Peake) proposed a vote of thanks to Mr. Thomas Morgans for his valuable paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Mr. W. DAVID read the following paper on "The Position of and Method of Working Bath Stone in the Quarries of the Bath Stone Firms":—

THE POSITION OF AND METHOD OF WORKING BATH STONE IN THE QUARRIES OF THE BATH STONE FIRMS.

By W. DAVID.

This paper relates to two subjects—the one of interest to commercial men, and the other dealing with the scientific conditions of the working and geological position of Bath stone known as the Great or Bath Oolite, which is now extensively worked in the Bath district. This paper is divided under two headings:—(1) The geological position of the marketable beds of freestone or Great Oolite; and (2) the method of winning this valuable building-material.

Geological Position.—The lower members of the Jurassic group of rocks are probably much more fully developed in the Bath district than in any part of Great Britain, and may here be divided into three distinct layers or beds of Oolitic Limestone, namely:—(1) The Inferior Bath Oolite, (2) the Bath or Great Oolite, and (3) above this series Forest Marble and Cornbrash. The writer will, however, confine his remarks to the Bath Oolite, worked so extensively in the quarries known as Box Ground, Corsham Down, Monks Park, Farleigh Down, Bradford, Westwood Ground, Stoke Ground and Combe Down, in which district we meet with, under the Forest Marble, the following:—(A) The Upper Ragstones, (B) the fine Freestones used for building purposes, and (C) the Lower Ragstones. These, combined, vary in depth from about 70 feet to a little over 100 feet, depending to a great extent upon the locality.

The Upper Ragstones.—These beds consist of coarse, shelly limestones of an oolitic nature, but very hard and tough, of a brown colour, and of little or no use for building purposes.

The Fine Freestone-beds.—These beds, or the Bath stone series, are found underneath the hard Rag, varying in texture also accord-

ing to the district from which they are raised. The analysis of Bath stone is as follows:—Carbonate of lime, 97·2 per cent.; oxide of iron and alumina, 1·6 per cent.; silica, 1 per cent.; and carbonate of magnesia, 0·2 per cent.

The Lower Ragstones.—These beds occur beneath the fine Freestone-beds which are found throughout the whole district, resting upon the Fullers Earth, which is worked to a moderate extent near Bath. This Ragstone is of a coarse, shelly nature and is a hard limestone, varying in thickness from 50 to 100 feet. This Lower Ragstone has been used in the construction of bridges in this neighbourhood, but it has proved to be a poor weathering stone and is considered of little value, and moreover it is costly to work.

In the construction of the Box tunnel, which was completed about the year 1841, a good deal of the quarries now being worked in the Box Ground and Corsham district were first discovered. In fact, the land to the north and south of the tunnel has been most extensively worked ever since, but it so happens that the Bath Oolite deteriorates as a commercial building-stone going north-eastward and south-westward from the Bath stone district.

Underneath the first Ragstone is a bed known locally as "capping," varying in thickness from 4 to 6 feet, generally a little hard but fine in the grain, and in former years it was not wrought on account of this hardness, but allowed to form the ceiling-bed. In these days, however, it is quarried and sent to the market, and this bed of freestone (together with the other workable beds) makes a total average thickness of 20 to 30 feet. These beds are usually regular, perfectly uniform in colour, and of fine texture, well suited for sawing and working, and free from fossils. The beds vary from 6 inches up to 6 feet in thickness, but an average thickness is perhaps 2 feet.

According to tests made by Mr. James Kirkaldy in 1880, the mean crushing-weight of the hardest quality of Monks Park Bath stone is 188 tons per square foot. While the greatest stress that comes upon any part of the masonry in St. Paul's Cathedral is less than 14 tons per square foot.

Method of Working Bath Stone.—The method of quarrying Bath stone has now become a matter of considerable importance,

inasmuch as about 2,000,000 cubic feet of freestone are raised during a year and forwarded to all parts of Great Britain and occasionally abroad.

In a few cases only have the Bath stone quarries been opened and worked by means of a free-drainage level; and in nearly all cases, therefore, it has been found more convenient to sink a slope-shaft dipping about 1 in 2 from the surface until it strikes the bottom of the working-bed. At the mouth of the inclined shaft a powerful engine and boiler is fixed, and by means of a wire-rope the loaded trolleys, carrying upwards of 10 tons of block-stone, are pulled up on tram-lines to the surface and so conveyed to the railway.

North and south of the Box tunnel, quarrying operations have been carried on to a very large extent in these mines, from which the best beds of Corsham and Box Ground freestones have been taken, and very few persons indeed who travel by the Great Western railway through the Box tunnel have any idea of the extensive stone-mines lying on either side.

One system only of getting or winning the stone is in use throughout the whole of the quarries. The quarryman commences his operations in the top bed of the freestone and immediately underneath the Ragstone ceiling. A portion of the upper part of the freestone is removed a little at a time, and this excavation is made throughout the whole width of the working or stall. The top of the rock to the extent of 6 to 8 inches is removed, in order that a saw about 5 to 6 inches in depth may be introduced. The "picking" operation is carried out by means of a light pick about 6 pounds in weight, and as the work proceeds longer-handled picks are employed, driving in a distance into the rock eventually of about 5 to 6 feet. The width of the heading depends entirely upon the soundness of the ceiling-bed. The greatest width of a heading, about 35 feet, is in the Corsham district.

Great care is, of course, always taken to avoid danger to the workmen employed in the mines. Any tendency to "settle" is at once determined, propping is brought into use, and danger is thus guarded against.

Having completed a sufficient quantity of "picking" in a heading, a one-handled saw varying in length up to 7 feet is introduced, and after the rock is sawn down to the next natural bed (a depth of several feet) the block is lifted by the introduction

of wedges into the lower or parting-bed at the bottom of the block, and by means of a long heavy bar it is broken away at the back and thus shaken from its natural position. It is then drawn down by a powerful crane, which is capable of displacing blocks of stone weighing perhaps 12 or 14 tons, although when finally squared up they rarely exceed 8 tons. The broken joint on the end of the block is afterwards chopped down with an axe, and the block made shapely and ready for the market. The blocks are stacked around the crane and eventually loaded upon trolleys and conveyed to the foot of the slope-shaft.

When the first block has been removed, the workman has access by that opening to the back of the mass of stone; and advantage is then taken of the opening to introduce the saw transversely, thus separating the block from the solid rock and avoiding any further breaking-off. One block of each face is all that is broken from the rock. This process is followed from the top to the bottom of the Freestone-beds.

Conclusion.—The Saxon church at Bradford-on-Avon was erected in the early part of the eighth century, and is still in existence to testify to the endurance of Bath stone. Malmesbury Abbey was also erected in the eighth century, Lacock Abbey in the thirteenth century, and Longleat (the residence of the Marquis of Bath) in the sixteenth century, in each of which Box Ground stone was used and is at the present time in a sound condition.

It should here be explained that no Bath stone, with the exception of the Box Ground weatherstone, is brought to the surface during the winter months, and in the Corsham district in particular very large quantities are stacked in the old headings underground until the beginning of April in each year. The stone is then raised to the surface and built into large stacks for the purpose of being seasoned or summer-dried. The "quarry-sap" dries out of even the largest blocks in the course of a couple of months, and a supply of seasoned stone is then available for the coming winter. During the summer months, freshly-quarried stone is sent away direct to the customers as it is dug, the stone drying quickly when it is sawn into smaller pieces and almost before it can be fixed in the building. After the stone is exposed to the weather, a hardened face or skin is developed which protects it against atmospheric influences.

Another matter of great importance in the use of Bath stone is to see that all blocks are laid on their natural bed, as they lie in the quarry and with the grain of the stone. By this means, the weather is prevented from causing the stone to peel and perish, which would otherwise happen if placed face-bedded.

No durable stone can be so economically carved or moulded as the Bath Oolite. Worked stone for an average building can be supplied to architects' drawings and prepared ready for fixing, delivered on rail at the quarry station, at about 4s. per cubic foot, compared with about 8s. per cubic foot for Portland stone, and even more for Yorkshire and similar hard stones from the north of England or Scotland.

In conclusion, the writer may say that the resources of marketable Bath stone are very great, and personally he fails to see that there can be any scarcity of this material for an exceedingly long period, especially if the land yields anything like the present output per acre.

The PRESIDENT (Mr. H. C. Peake) moved a vote of thanks to Mr. David for his interesting paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

DISCUSSION ON MR. HOSKOLD'S "NOTES UPON ANCIENT AND MODERN SURVEYING, ETC."*

Mr. BENNETT H. BROUGH (London) wrote that the multifarious duties of mining-engineers left little time available for antiquarian research, and consequently so interesting a subject as the evolution of surveying-instruments had hitherto received no attention in the *Transactions*. In 1892, he published some notes on the history of mine-surveying in a course of Cantor lectures, delivered before the Society of Arts,† and the subject has been exhaustively dealt with in France by Colonel Laussédat, in 1898,‡ and in the United States by Mr. Dunbar D. Scott, in the same year.§ To the discussion of the latter paper, Mr. Hoskold furnished an

* *Trans. Inst. M.E.*, 1900, vol. xix., page 171.

† *Journal of the Society of Arts*, 1892, vol. xl., page 798.

‡ *La Topographie dans tous les Temps*, Paris, Gauthier-Villers, 1898.

§ *Transactions of the American Institute of Mining Engineers*, 1898, vol. xxviii., page 679; and 1899, vol. xxix., page 931.

important written contribution, and it is gratifying to find that he has elaborated this into a paper for our *Transactions*. There are, however, several statements in his paper that are open to criticism, and it is unfortunate that, in a historical paper of this kind, fuller references to authorities are not given. In dealing with questions of priority it is impossible to exercise too great care in ensuring the accuracy of the references given. Yet Mr. H. D. Hoskold gives no bibliographical foot-notes, and when he refers to the titles of books, he has obviously trusted to his memory. For example, *Subterraneous Surveying** is not the title of Houghton's book published in 1681; and the facsimile of a page of Thomas Digges' *Pantometria*† is not copied from the 1571 edition as stated, but from that of 1591. It was Leonard Digges who invented the theodolite, and the book to which reference is made was "Framed by Leonard Digges, Gentleman, lately finished by Thomas Digges, his Sonne, London, 1571."

The author adopts the view that the magnetic needle was first introduced into Europe about the year 1310.‡ This is the view of Italian authors, who claim for their countryman, Goïa, a Neapolitan pilot, who lived in 1300, the honour of the invention of the compass. There is, however, extant a poem by Guyot de Provins of the year 1190, in which there is a clear description of the compass, and a statement to the effect that the Pope should be to the faithful what the pole star and the compass are to sailors. The French priority of invention is supported by the fact that on compass-cards in all countries the north is marked with a *fleur-de-lis*. In 1834, Klaproth, in a letter to the Baron von Humboldt, gave the results of his researches showing that the mariner's compass was of Chinese origin, and was defined in Chinese dictionaries of the years 121 A.D. and 265 A.D. It appears to have been introduced into Europe through the intermediary of the Arabs.

The author is scarcely justified in stating that "the system of mine-surveying with the exclusive use of the theodolite and the co-ordinate mode of plotting the survey"§ was introduced in his book in 1863. Budge's *Practical Miner's Guide*, published in 1825 (not 1845 as stated by the author) describes the co-ordinate method of plotting, and Rickard's *Miner's Manual*, 1859, deals

* *Trans. Inst. M.E.*, vol. xix., page 184.

† *Ibid.*, page 182.

‡ *Ibid.*, page 181.

§ *Ibid.*, page 215.

with the use of the theodolite underground. On the Continent, Dr. Erasmus Reinhold in 1574 described the co-ordinate method of plotting mine-surveys, while Prof. H. C. W. Breithaupt, in 1798, was the first to use the theodolite underground combined with trigonometrical calculation of the results. In 1796, experimental mine surveys were carried out by the Polish Lieutenant-General Komarzevesky and by Prof. Lempe at Freiberg in Saxony, with an astrolabe, constructed by Ramsden, and modified for use underground by Studer, a Freiberg instrument-maker. A report on these experiments was communicated to the National Institute in Paris on August 4th, 1802; and it was in consequence ordered by the Government that this method of surveying should be adopted in all French mines. In the collieries of Rhenish Prussia, surveying with the theodolite became very general in the year 1835, when Mr. F. W. Breithaupt of Cassel began regularly to supply a useful type of mine-theodolite, and when Mr. Prediger of Saarbrücken had conducted with conspicuous success a theodolite-survey for setting out the Ensdorf adit-level some 3,300 feet in length Moreover, the mine-theodolite devised by Prof. C. Combes of the Paris School of Mines, and described by him in the *Annales des Mines* for 1836,* was similar to Mr. Hoskold's, in that it was of the transit type. The telescope was, however, supported on one side only.

In his reference to photographic surveying, the statement that in phototheodolites, the telescope is fixed "concentrically" is obviously a misprint for eccentrically.† Mr. Hoskold does not appear to have followed the great progress that has of late years been made in this branch of surveying, in consequence of the remarkable results obtained by Colonel Laussédat, Mr. J. Bridges Lee, and other inventors. In the chapter on photographic surveying in his (Mr. B. H. Brough's) *Treatise on Mine Surveying*,‡ he gave a long list of titles of works on the subject, and in describing its application to mining work referred to the results obtained at the Carrara marble-quarries, at the Styrian iron-mines, and in the Klondyke district.

Colonel A. Laussédat (Directeur du Conservatoire National des Arts et Métiers, Paris) wrote that he had read Mr. Hoskold's in-

* Vol. ix., page 81.

† *Ibid.*, page 211.

‡ Eighth edition, London, 1901.

teresting paper, but he had, unfortunately, not the time to submit all the observations which this paper suggested to him. He did not hesitate to recognize that the author had given proofs of wide learning and that his paper contained references to documents little known, but of very great interest. He would, however, be glad to be allowed to criticize one portion in noting that the information given in Mr. Hoskold's valuable paper is much more abundant for past periods than for the present day. The recent transformation introduced by the employment of photography did not seem to him to be sufficiently brought forward, and he was astonished that Mr. Hoskold had only pointed out rather inaccurate instruments,* and but two photographic instruments employed specially for topographical plans. There had been for some time a valuable literature of the art which is designated under the name of metrophotography, photogrammetry, topophotography, etc., in the different countries of Europe and the United States, and even in Australia. He had the honour at the recent International Geographical Congress held in London, in 1895, to send a large number of papers and a model of a phototheodolite, which were presented in the name of the Geographical Society of Paris (which had asked him to do so), as well as in his own name, by Prince Roland Bonaparte and by Mr. Schrader. He was unfortunately prevented from attending that meeting, and deeply regretted it, because he would have been able to press the matter more elaborately than his two compatriots had done. His most detailed papers on the subject were:—"L'Art de lever des Plans"† and "Recherches sur les Instruments, les Méthodes et le Dessin Topographiques."‡

Mr. FRANK OWEN (Tarkwa, Gold Coast) wrote that Mr. H. D. Hoskold stated that "the Peruvian expedition measured two base lines, one near Quito . . . and the other near Cotopaxi."§ Surely these places are incorrectly described as "Peruvian," being situated in the Republic of Ecuador, which, in the time of the old Spanish dominion formed part of the viceroyalty of Caracas (Vene-

* *Trans. Inst. M.E.*, vol. xix., pages 210 and 211.

† *Revue Générale Internationale, Scientifique, Litteraire et Artistique*, March to July, 1896, page .

‡ *Annales du Conservatoire des Arts et Métiers*, series 3, vol. i., pages and ; and vol. ii., page .

§ *Trans. Inst. M.E.*, vol. xix., page 186.

zuela), and in 1823 was joined to the original republic of Colombia, as founded by Simon Bolivar. An account of the monuments erected by the French astronomers (since destroyed by the natives of the country to build a flour-mill), is given by Mr. Edward Whymper in his charming book, *Travels amongst the Great Andes of the Equator.* With reference to historical triangulations, he remembered reading a fine old book descriptive of South America, published early in the last century, in which is described Humboldt's triangulation to ascertain the width of the Orinoco (about 1 mile), at San Thomé de Angostura, now known as Ciudad Bolivar, in Venezuela.

Mr. H. D. Hoskold wrote that as he had stated in his paper, Budge published a very useful work, *The Practical Miners' Guide*, in 1845, Messrs. Longman, London,* and any one well acquainted with British Engineering literature might have known that it was the second, and not the first edition of 1825, which he had referred to.

Mr. Rickard, in his book, had introduced the words "plain theodolite;" but he described this instrument to be nothing more than "Wilton's improved miner's dial," or circumferentor; the "two parts," or divided circle and vernier circle, carrying the plain sights were held together with a "pin," and motion was given to it and the plain sights by a "rackwork." It was not therefore, such an instrument as we have frequently considered and described as a theodolite, and transit-theodolite proper, since 1863.† Neither did Mr. Rickard introduce any system of mine-surveying by the use of such an instrument as that represented by Fig. 19 of the writer's paper.‡

The words employed by the writer in his paper cannot be assumed to mean that Fig. 3 was taken from the old book of Digges, 1571, for it is separated from the preceding passage by a full stop: moreover, the diagram representing the theodolitus is the same in both the editions of Digges' work.§ Mr. Brough is therefore very unhappy throughout in his criticism.

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* *Trans. Inst. M.E.*, vol. xix., page 214.

† *Miners' Manual*, page 158.

‡ *Trans. Inst. M.E.*, vol. xix., page 238.

§ *Ibid.*, vol. xix., pages 181 and 183.

DISCUSSION OF MR. A. R. SAWYERS' PAPER ON "THE PORTUGUESE MANICA GOLD-FIELD."*

Mr. Frank Owen (Tarkwa, Gold Coast), referring to the occurrence of graphitic schist in the gold-fields of Manica land,† wrote that a similar formation is to be found in connection with the lenticular ore-bodies of the Adansi and Ashanti countries, in West Africa, where it is almost invariably looked on as a sign of rich ore. The graphite schist usually occurs on the hanging-wall of the lode, being so black in colour as to make the tunnel look more like a coal-mine than a gold-mine, while the foot-wall is either micaceous or talcose schist. This formation makes most treacherous ground for mining, and very close and careful timbering is required, otherwise large masses up to several tons in weight are liable to fall at any time from along the line of cleavage of the graphite schists. At the Frias mine of the Tolima Mining Company, Limited, in the republic of Colombia, South America, where graphitic schist sometimes forms the walls of a large and very rich lode of argentiferous galena and blende, it is regarded on the contrary, as a precursor of an impoverishment of the ore-body.

DISCUSSION OF MR. G. K. RADFORD'S PAPER ON "MINING FOR GOLD IN THE AURIFEROUS GRAVELS OF CALIFORNIA, U.S.A."‡

Mr. G. K. Radford, replying to Capt. C. C. Longridge's remarks, said that with some knowledge gained by actual observation of the methods and appliances used in alluvial mining in California, he was not aware of any special ingenuity in the application thereof, other than those described in the paper, and common to such operations throughout the world.

As to the reasons for (1) employing a wooden flume in a tunnel, he (Mr. Radford) owed an apology for a printer's error, "in" should read "to," as there is not any flume in the tunnel; § (2) the flume was constructed in place of a ditch, because there was not any ground in which to form the latter, and to have substituted a pipe would not have been economical; (3) doubtless a semicircle is theoretically the best water-carrier, but there were practical and

* *Trans. Inst. M.E.*, 1900, vol. xix., page 265. † *Ibid.*, page 278.

‡ *Ibid.*, 1899, vol. xvii., page 452; and vol. xix., page 140.

§ *Ibid.*, vol. xvii., page 458.

economical reasons against the adoption of such a form. He (Mr. Radford) presumed that Capt. Longridge referred to the tensile strength of steel plate, before being manufactured into pipe, and not the safe strain therein. The question of rivetting was raised for the purpose of eliciting some practical observations thereon, as there is no reason why there should be any greater variation than in rivetting for boiler-work.

No expansion-joints were provided in the pipe-line except leather ones at the inlet and outlet-ends, nor are they customary on pipe-lines.

DISCUSSION OF MR. J. EMERSON DOWSON'S PAPER ON "METRIC WEIGHTS AND MEASURES."*

Mr. Edward Halse (Colombia) wrote that, although in most Spanish-American countries the metric system of weights and measures had been adopted as the legal standard, older systems, handed down from past centuries, are far more commonly in actual use.

In Mexico, for instance, the standard measurement on the railways is the kilometre, but leaving these, the *legua* or league of 5,000 *varas*† is very much in evidence. Travellers on mule-back admit that the legua is a very variable quantity: there are short leagues and long leagues, principally the latter.

In mines, contracts are usually set and measured by the metre, and in the cities and larger towns dry goods are frequently sold by the same standard; but in the provinces generally the Spanish vara (yard) is the measure actually in use. The vara is 2·749578 feet, or $2\frac{3}{4}$ feet or 33 inches nearly, so that it is almost as much short of an English yard as the metre is in excess of it.

Turning to weights, the kilogramme is largely used on railways, and in warehouses, workshops and mine store-houses generally; but the commodities of the country are bought and sold in *cargas* and *arrobas*, or in *quintales*. A *carga* in Spain is a mule-load, or 380 Spanish pounds. It is obvious, however, that mule-loads will vary according to the nature of the road; hence we find that in Mexico a carga is 300 pounds or 12 *arrobas*; in Peru it is 250 pounds or 10 arrobas; and in Colombia, where the

* *Trans. Inst M.E.*, 1899, vol. xvii., page 326; and vol. xviii., page 408.

† In Spain, a legua contains 6,650 varas; but in Cuba, only 5,078 varas.

roads are unusually bad, it is only 200 pounds or 8 arrobas. So that with regard to roads, there would appear to be four degrees of comparison. The quintal, hundredweight or Spanish centner contains 100 Spanish pounds or 4 arrobas, and is equivalent in Mexico to 101·444 British pounds.*

In some of the classical mining districts of Mexico, assays of silver-ore are returned as so many *marcos* and *onzas* to the carga, or to the *monton* of 20 quintales. The monton varies in the different mining districts from 0·608664 to 1·6231 tons of 2,000 pounds avoirdupois. A marco (mark) is 8 Spanish ounces (onzas), and is further subdivided into *ochavas*, *adarmes*, *tomines* and *granos*.† one marco is 8·1184 ounces avoirdupois or 7·3995 ounces troy.‡

The Spanish pound therefore is in excess of the British pound avoirdupois, and the onza is more than the ounce avoirdupois (1·0148), but less than the ounce troy (0·925 nearly).

In Columbia, gold is almost invariably weighed by the *castellano*, 100 of these being equal to the Spanish pound, and is subdivided into *pesos*, *tomines* and *granos*.§ One castellano weighs 71 grains troy, and 1 ounce troy weighs 6·76 castellanos nearly; 1 castellano weighs 0·147893 ounce troy so that, on account of this unfortunate repeating decimal it is impossible to convert castellanos into troy ounces exactly.

In Mexico, 50 castellanos equal 1 *marco de oro* (gold mark).‖

A volume might be written on the weights and measures other than the metric system actually in use in Spanish-American countries, but it would require a W. L. Alden to emphasize the fact how "life's little worries" are increased thereby.

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* The quintal of Castile or Madrid contains 101·61 pounds avoirdupois; the *arroba*, 25·4025 pounds avoirdupois; and the libra (pound) weighs 1·0161 pound avoirdupois.

† 1 onza equals 8 ochavas (eighths), 1 ochava equals 6 tomines, and 1 tomin equals 12 granos.

‡ To convert, say, 18 marcos of silver per monton of ore to ounces troy per ton of 2,000 pounds, multiply 18 by 7·3995, and 20 by 101·444 pounds. The result gives 133·191 ounces of silver in 2,028·88 pounds of ore, or by proportion, 131·29 ounces per ton of 2,000 pounds. If the returns are given in cargas, it must be remembered that 300 pounds Spanish are equal to 304·332 pounds avoirdupois.

§ The castellano equals 2 pesos, 1 peso equals 4 tomines, and 1 tomin equals 12 *granos*.

‖ On October 25th, 1649, the value of the castellano of gold of 22½ *quilates* (carats), was fixed at 17 *reales* 11 *maravedis*. *Historia General de Real Hacienda*, Mexico, 1845-53, vol. i., page 23.

DISCUSSION OF MR. HARRISON F. BULMAN'S PAPER ON "THE KALGOORLIE GOLD-MINES, WESTERN AUSTRALIA."*

Mr. EDWARD HALSE (Colombia) wrote that Mr. H. F. Bulman in his interesting and instructive paper, quoting Mr. G. W. Card, enumerates the principal constituents of the country-rock of the Kalgoorlie gold-area, and contents himself with saying that it is of igneous origin.† Specimens of the country-rock and lode-stuff taken by Mr. W. Frecheville,‡ were submitted to Mr. G. W. Card for microscopical determination. Two samples of green rock, one from the Lake View mine, the other from the Great Boulder, were stated by him to consist of "an acid igneous rock, either granite or porphyry, the latter I think." But as the term "porphyry" refers to structure rather than composition, the selection of the name is somewhat unfortunate. A specimen of grey country-rock from the Australia lease, Mr. Card considers to be "a highly altered granite-rock;" that from the Australia East lease is pronounced to be "a highly altered igneous [quartzless] rock of doubtful nature." Typical ore from the Kalgoorlie lease "is a very much altered igneous rock, probably granite;" that from the Australia lease is probably "a highly crushed granite." Messrs. E. F. Pittman and G. W. Card agree in regarding the area as of igneous origin, "consisting of acid rocks, largely granitic perhaps."

Prof. W. W. Watts,§ who examined microscopically a specimen of green country-rock a little south of the Great Boulder main-reef mine pronounced it to be a quartz-diorite, while a specimen of what appeared to the writer (Mr. E. Halse) to be a granitic dyke, forming the hanging-wall of a telluride-bearing lode, he determined to be "a granophyre or aplite—such a rock as might be a dyke from a granitic mass," while specimens of lode-stuff, containing tellurides from the Kalgurlie and Hannan's Star mines, looked like "crushed aplites or granophyres."

According to Prof. G. A. J. Cole, aplite "is the old 'binary

* *Trans. Inst. M.E.*, 1899, vol. xvii., page 349; and vol. xviii., page 344.

† *Ibid.*, vol. xvii., page 350.

‡ "Notes of a Visit to the Gold Mines at Kalgoorlie, Western Australia," *Transactions of the Institution of Mining and Metallurgy*, 1898, vol. vi., page 140.

§ *Trans. Inst. M.E.*, 1898, vol. xiv., pages 289, 295 and 296.

granite,' being practically composed of quartz and orthoclase only. . . . Occurs often as veins in granite." Granophyre is a variety of eurite, or fine-grained compact granite; some granophyres are probably varieties of quartz-aphanite.

Prof. J. F. Kemp* examined specimens of the so-called "bluestone" country of Kalgoorlie, and found it to be "an altered basic eruptive," but "only indefinite alteration products could be detected, apparently of chloritic and serpentinous nature, together with some secondary quartz. Rather large platy crystals of leucoxene are in the rock, having still preserved on their surfaces the triangular markings characteristic of the original ilmenite." The green rock of the surrounding barren area was determined in Perth, and proved to be essentially the same, with the addition of a little olivine.

Mr. H. P. Woodward† describes the Kalgoorlie range as consisting "of hard, fine-grained horblendic schists, intersected by numerous diorite dykes."

Mr. Edward S. Simpson‡ says that "the auriferous lodes in all the mines at the south end of the camp (Boulder) are in re lity dykes of highly foliated felstone [devitrified pitchstone of the rhyolite-group], impregnated with carbonates of lime, etc., and also with auriferous pyrites and tellurides of the noble metals."

The Kalgoorlie and other similar deposits in Western Australia have also been described as "zones of crushing and fissuring in diabase and highly altered slates, from which channels impregnation and some replacement of the country-rock have taken place."§ Diabase, according to Prof. Cole, is "a good field-term for altered greenish rocks allied to diorite, gabbro, aphanite or dolerite."

From these and other observations it would appear that the area is in reality a complex of igneous and metamorphic rocks. Granitic dykes, running in a general north-north-westerly and south-south-easterly direction, are conspicuous, as well as masses and

* "Geological Occurrence and Associates of the Telluride Gold-ores," *Mineral Industry*, 1897, vol. vi., page 318; and Mr. George J. Bancroft, "Kalgoorlie, Western Australia, and its Surroundings," *Transactions of the American Institute of Mining Engineers*, 1898, vol. xxviii., page 88.

† "The So-called Lode-formations of Hannans, and Telluride Deposits," *Transactions of the Institution of Mining and Metallurgy*, 1898, vol. vi., page 14.

‡ Discussion on Mr. Bancroft's paper, *Transactions of the American Institute of Mining Engineers*, 1898, vol. xxviii., page 808.

§ *Mineral Industry*, 1898, vol. vii., page 299.

dykes of eruptive rocks of different ages.* Associated with the ore-bodies are lenses of peculiar slate, stated by Mr. Bancroft to be graphitic.† It is not improbable that in depth the basement-rock will be found to be unaltered granite.

To the list of tellurium minerals occurring at Kalgoorlie, given by Mr. Bulman, should be added native tellurium‡ and tetradymite (telluric bismuth), the latter of which was detected by the writer (Mr. E. Halse) in one of the veins of the district.§

DISCUSSION OF MR. H. FOSTER BAIN'S PAPER ON "AN AMERICAN LONGWALL MINING MACHINE."‖

Mr. Foree Bain (Chicago) wrote that he was confident that any plant of electric coal-mining apparatus, wherein more than 250 volts are used would be a failure from one cause or another. He thought that 250 volts was the maximum and proper voltage for an electric-power plant for coal-mining. In his practice, motors had been wound so that the current-density of the armature, with a normal load, would not exceed 2,500 ampères per square inch, and for the short time the machine was employed this density might be more than doubled. The alternating periods of rest and use would permit this excess in coal-mining machinery, where it would not be permissible with motors running at a constant load for a long period of time. With the cutter-bar machine, he had made cuts 5½ feet under, 4½ feet wide and about 4 inches high in 3 minutes, and backed out the machine in less than 2 minutes in Hocking

* Specimens taken by Mr. Bancroft, from two dykes, one at the south-western corner, and one at the north-eastern corner of the field—about 1 mile from the rich mines - Prof. Kemp found to contain "recognizable traces of dark-brown horn-blende, originally in large crystals, which were altered to more or less fibrous masses of actinolite or tremolite," *Mineral Industry*, 1897, vol. vi., page 319, and Mr. Bancroft's paper.

† According to Prof. Kemp, "thin sections of this slate revealed an excessively finely crystalline mass, with blotches of red hematite, apparently from decomposed pyrites-crystals. All through the mass of the rock are minute prismatic crystals, of high refractive index, and doubtless rutile, as is sooften the case in slates. No quartz-grains could be detected, but the mass of the rock was the feebly refracting or practically isotropic aggregate, characteristic of soft slates. In the hand specimen the rock has every appearance of being a soft clay-slate," *Mineral Industry*, 1897, vol. vi., page 319, and Mr. Bancroft's paper.

‡ "The Minerals which accompany Gold, and their bearing upon the Richness of Ore Deposits," by Mr. T. A. Rickard, *Transactions of the Institution of Mining and Metallurgy*, 1898, vol. vi., page 194.

§ *Trans Inst. M.E.*, 1898, vol. xiv., page 295.

‖ *Ibid.*, 1900, vol. xix., page 144.

Valley coal, Ohio, and unless the knives strike some unusual obstruction the power would never exceed 15 electric horsepower and usually averaged much less. For a cutter-bar machine, he used a 15 horsepower motor, which would have a capacity to deliver 30 horsepower for short periods of time. In practical experience, he never found that it was necessary to use more than 20 horsepower; and he thought he could safely say that the 50 per cent. factor is sufficiently safe for practical purposes. With a chain-machine making an undercut neither so long nor so high in the same time and in the same coal, not more than 6½ to 8 horsepower was required. He had made a 12 horsepower electric motor, and connected the shaft directly to the chain-sprocket, and ran the motor at a normal speed of 125 revolutions per minute. This was an extraordinarily slow speed, but it worked very satisfactorily and did not require more than 6½ to 7 horsepower when in operation.

In his opinion, the chain-machines that were now in operation generally throughout the United States did not require more than 8 horsepower on an average for doing the work required of them, and he would recommend that the current-density in the armature be run up to at least 5,000 to 6,000 ampères per square inch of conductor for short periods of time.

DISCUSSION OF MR. JOSEPH HASSALL'S PAPER ON "MINING IN THE SOUTHERN KLERKSDORP GOLD-FIELDS, WESTERN TRANSVAAL."*

Mr. Joseph Hassall wrote, thanking the members of the Institution for the consideration given to his paper, and expressed his indebtedness to Mr. John M. Liddell, for his able criticisms on the data that he had been able to place before them and the additional detail suggested by him for a further paper.

There were few geological points that had led to greater controversy among local mining men, than that of the true trend of the reefs of the Rand Main Reef Series, westward from Witpoortje.

Eastward of Witpoortje, however, for some miles, until the vicinity of Boksburg was reached, the distinctive features were remarkable, consequently it was by no means unreasonable to

* *Trans. Inst. M.E.*, 1900, vol. xix., page 377.

suppose that the developments of future mining would, with certainty, locate still further eastward and westward the reefs of the Main Reef Series: where at present on account of disturbances, or the covered nature of the country, all statements as to the true trend of the reefs are problematical.

Quartz and quartzite cross-leads so far as he knew have not been discovered in the mines described in his paper. The gold-bearing conglomerates with their accompanying country-rocks, belong in all probability to a far later period than the quartz and quartzites of the Sheba-line; and from this cause and the difference in the contour of the surface, the mining conditions of Klerksdorp (Schoonspruit gold-fields) and those of Barberton (De Kaap gold-fields) are in many ways dissimilar.

The average tons of ore stoped per head varies considerably in different mines. The averages taken in the southern Klerksdorp mines allow for all the natives engaged in the breaking of the ore, and its transit from the working-faces to the boxes; this includes drillers, shovellers and (in cases where there is but a slight inclination) trammers. The formation is far more irregular and mining is more difficult than in the Rand; therefore the average mining costs of different mines vary also more considerably.

Where the dip of the reef, and the regularity of the foot-wall is favourable under the conditions already given, the tonnage average per native per shift will reach 30 cwts., but where an unfavourable dip or an irregular foot-wall has to be contended with the average is sometimes as low as 10 cwts.

Machine-drills are little in use in the gold-fields under discussion, practically all work being done by hand, and as a general average of feet driven per head per day, the following can be taken:—In connecting No. II. and No. III. shafts on the Niekerk mine, the distance driven on the reef was 310 feet, the drive was 5 feet by 6 feet, the average depth on the incline 108 feet, and the vertical depth 83·6 feet. The country-rock traversed consisted of diabase, conglomerates and quartzites (altered sandstones); the driving from the two faces averaged a total of 5 feet per diem, the cost was 35s. per foot; which covered all expenses up to the delivery of the ore and waste to the skips, in the inclined shafts. Eight native drillers, 16 native shovellers and tram-boys, and 2 European miners as overseers were engaged over two shifts of 10 hours each during a day of 24 hours.

In respect to European versus native labour, now that thousands of natives have for many years been working in the Transvaal gold-mines, it is found for such work as onsetting, banking, etc., that when under the control of an overseer, who is invariably a European, intelligent natives are sufficiently advanced to compare favourably with the European labourers generally employed, for that class of work, while the native costs less.

Shafts are generally put down in duplicate at distances from 300 feet to 1,000 feet apart, according to circumstances. They follow the inclinations of the reef as far as possible, and one shaft is kept ahead of the other, levels also being driven at intervals according to the angle of dip, thus causing a natural ventilation to be created.

The deep-level mines of the Rand, now being developed, are necessarily sinking vertical shafts, to reach their reefs lying at great depths, and must perforce adopt artificial ventilation; but in the Klerksdorp gold-fields, where no great depths have been reached, all the ventilation required is found to be given, when the mines are opened up as above.

Timbering depends on the nature of the ground to be passed through, and dividers can be dispensed with if necessary.

On the matter of dual directorates he was pleased to see that the members agreed with him, and regretted that in replying to his own paper, he could necessarily only cursorily refer to the important questions raised by Mr. Liddell on ventilation, shaft-furnishing and labour; but as they were of such importance, and covered such an immense amount of detail, especially useful to a mining district as yet in its infancy, he trusted at some future time, that occasion would be found to bring them forward again.

Mr. J. M. Liddell (Stocksfield) wrote that he was interested in the notes, which Mr. Hassall had kindly added to his paper. He agreed with his opinion that there is too much material for exhaustive discussion in his present paper. He would remark, however, in reference to the labour question, that it has been profoundly disturbed by recent political events, and that labour-supply will have to be reconstituted under new conditions. It is of vital importance, and the time appears to him (Mr. Liddell) most opportune, for considering whether it should be reconstituted on a black or on a white basis? If black, the obtaining custom

of blacks to work spasmodically for a few months, or a few years at a time, should be changed for that of continuous mining throughout their working life. The difficulty would thus arise of having to establish large urban populations of blacks, including women and children; of securing their attention to work and their satisfactory government under the uncertainties of the laws relating to natives. It is thus most important to discover whether the same work may not be performed at less cost and risk by white populations, under a government which shall reverse the late policy of making life as expensive and difficult as possible for white miners, and shall instead afford them all the help and protection that is usual in British colonies.

Mr. W. N. Atkinson (H.M. Inspector of Mines) proposed that a hearty vote of thanks be accorded to the Lord Mayor of Bristol, for the use of the Guildhall, and for his courtesy in welcoming the Institution to Bristol; also to the Bristol Tramway Company Limited, for permission to visit their power-station; to the Mayor of Bath, and to Major Davies, for permission to visit the Roman baths and antiquities found in that town; to the Bath Stone Firms, Limited, for permission to visit their stone-mines; to the owners of St. Cuthbert's lead-works; and to the Bishop of Wells and Dean of Wells for according facilities to view the cathedral, palace-grounds, etc.

Mr. W. Beattie Scott (H.M. Inspector of Mines), seconded the resolution, which was heartily adopted.

Mr. H. St. John Durnford (Pontefract) moved that a hearty vote of thanks be accorded to the members of the local Committee for the excellent arrangements made for the reception of the members.*

* The Reception Committee consisted of the Right Honourable the Lord Mayor of Bristol, Sir Herbert Ashman, President; Messrs. J. S. Martin, H.M. Inspector of Mines, Bristol, Chairman; T. Forster-Brown, M. Inst. C.E., Stoke Bishop; J. McMurtrie, F.G.S., Mining Engineer, Radstock; J. Batey, Mining Engineer, Coleford, Bath; G. C. Hewitt, Assoc. M. Inst. C.E., Coalpit Heath; J. R. Bennett, Mining Engineer, Bristol; Thos. Hy. Yabbicom, M. Inst. C.E., Bristol; Thos. Morgans, M. Inst. C.E., Bristol; P. Addie, City Valuer, Bristol; and W. David, General Manager, Bath Stone Firms, Limited, Bath; and Mr. Nicholas Watts, Assoc. M. Inst. C.E., Lloyd's Bank Buildings, Bristol, Secretary.

Mr. JAMES BARROWMAN (Hamilton) seconded the resolution, which was cordially approved.

Mr. JAMES MCMURTRIE (Radstock) proposed a vote of thanks to Mr. H. C. Peake for his services in the chair.

Mr. J. S. MARTIN (H.M. Inspector of Mines) seconded the resolution, which was unanimously adopted.

The following notes record some of the features of interest seen by visitors to works, etc., which were by kind permission of the owners open for inspection during the course of the Bristol Meeting on September 18th, 19th and 20th, 1900: —

THE RIVER AVON GORGE.

BY Prof. C. LLOYD MORGAN, F.R.S., UNIVERSITY COLLEGE, BRISTOL.

Between Bristol and Avonmouth, a remarkably fine geological section is exposed comprising several features of special interest. The Hotwells Landing-stage very nearly marks the point where the Millstone Grit—the "Farewell Rock" of the miner, since it lies beneath the Coal-measures—crosses the river. In the open country to the south, the Lower Coal-measures lie beneath a comparatively thin sheet of Triassic rocks. To the north, the marine Lower Carboniferous series, with its Mountain Limestone slopes, cliffs and quarries, is deeply trenched and borders the Avon gorge—a picturesque valley spanned by the Clifton suspension-bridge. Between these lies the band of Millstone Grit on which Windsor Terrace on the Gloucestershire side is built. This band, from 400 to 500 feet in thickness, is followed by alternations of sandstone, limestone and shales, called the Upper Limestone Shales in this part of England; and about 600 feet of these beds, which form wooded slopes on the Somerset side, are succeeded by the more solid Mountain Limestone on which the buttresses of the suspension-bridge are based.

After passing the suspension-bridge, on the Clifton side, there is an abrupt change in the nature of the rocks. The massive grey

limestone of Observatory Hill abuts with a clean-cut face, sloping steeply southwards, on reddish beds, torn, twisted and contorted. Here a great fault crosses the series, by which the rocks to the south have been thrust over the contorted beds of Upper Limestone Shales and Millstone Grit. The vertical displacement is nearly 1,200 feet: the thrust and dislocation cause a repetition of the beds which have been passed through from the landing-stage to this point; and the solid limestone is not again reached for about 1,500 feet, where the quarries in the Upper Carboniferous Limestone are seen on either side of the river. There are no quarries in the succeeding part of the gorge, owing to the occurrence of a band of thinly-bedded limestones with grey shales, which render this part of the series economically worthless. They are followed by the Lower Carboniferous Limestone, which has been worked on the Gloucestershire side and is still extensively quarried on the Somerset side. From these beds have been obtained the numerous remains of shark-like fishes which are familiar to collectors of fossils. The entire Carboniferous Limestone series reaches a thickness of over 2,000 feet.

We have now reached the end of the deeper part of the gorge. Softer beds succeed, known as the Lower Limestone Shales, which have yielded more readily to rain and the forces of denudation, and hence form gentler slopes. They are succeeded by the Old Red Sandstone which forms part of a worn anticlinal arch. All the beds to the Bristol side of the axis of the arch dip gently south-south-eastward; while on the Avonmouth side they dip more steeply north-north-westward. The crown of the Carboniferous Limestone arch, overlying that of the Old Red Sandstone, has been worn away, about 10,000 feet of rock having been removed. The southern limb, which marks the spring of the arch on that side, forms Durdham Down; the northern limb forms a narrower tree-clad ridge readily visible on the Gloucestershire side, though it does not quite reach the river-bank—ending off as a physical feature at Penpole Point. Just where the river makes a sharp turn to the left before reaching Shirehampton, the Old Red Sandstone beds are seen with the dip proper to the northerly spring of the arch.

Here close observation will show that there are two sets of beds—the older set with the dip just mentioned, and on their upturned edges (affording a good example of unconformable

succession) flat-lying strata of Triassic age. Between the one set and the other, a long succession of strata is here wanting—all the Carboniferous, the Permian (nowhere found near Bristol), the Bunter (also here lacking), and much of the Keuper. The break in time between the two formations indicates therefore a period when deposition ceased in the neighbourhood, and denudation was active in the removal of strata.

Further down stream, the Hung Road, on the Somerset side, shows the flat-lying Triassic beds. It is formed of a conglomerate or breccia, with partly rounded, partly angular fragments of the older rocks, embedded in a grey or reddish matrix.

Beyond this point we reach the recent deposits, little above high-water mark, of the Severn alluvium.

AVONMOUTH.

The erection of a dock was begun in 1868. The lock was made 454 feet long between the gates, and 70 feet wide at the coping-level. The outer sill was formed at such a level as to give a depth of 38 feet in the lock at high-water of ordinary spring-tides. The dock had an area of 16 acres, and was not completed until 1877.

A dock was opened in 1878 at Portishead, a little over 2 miles below Avonmouth.

Since the Avonmouth dock was acquired by the Bristol Corporation, an extension has been made of the dock, giving about 1,600 feet of additional quay-wall. Lairage, chill-rooms, cold-stores, granaries, etc., have been provided. A floating dock has also been constructed, and a coaling crane has been provided.

As the lock could only take vessels varying from 425 to 430 feet in length, the practicability of lengthening the lock and constructing another pair of gates was considered, but looking to the nature of the foundations, it was considered advisable to get the additional length by forming a caisson-groove in the masonry at the outer end of the lock, and by means of a floating caisson it is possible for vessels 485 feet long to use the lock.

When required for use, the caisson is warped into position across the lock by means of hydraulic capstans placed on the shore; water is then admitted through large valves provided for the purpose, and the caisson is sunk until it rests in the bottom of the

groove. After the vessel has been locked, the water-ballast is ejected by means of compressed air acting directly upon the surface of the water in the compartments. There are 10 water-ballast compartments each fitted with filling and discharge-pipes controlled by valves worked by hydraulic power. The pressure-water necessary for the working of the hydraulic valves is obtained through a flexible hose connected to the hydraulic main on shore. The air under pressure for ejecting the water from the caisson is obtained from the receiver on shore by means of two flexible hose-pipes. The air-compressor is placed in the hydraulic engine-house and will deliver 1,000 cubic feet of air per minute at a pressure of 15 pounds per square inch.

The cattle-landing place and lairs, provided on each side of the entrance lock, are capable of accommodating 700 head of cattle and 4,000 sheep. There are also a sale-ring, eight slaughter-houses, and three chill-rooms, capable of taking 700 sides of beef. The refrigerating machinery is of the ammonia-absorption type, and has been in operation since 1889.

The cold-storage installation consists of six large rooms of a collective capacity of 110,000 cubic feet. The refrigerating machinery is of the ammonia-compression type, with cold air circulating in the stores. Duplicate plant has been provided throughout, each of the two plants being of ample power to refrigerate the six rooms. Each store has a lobby or ante-room placed between the store and railway-platform, where sampling can be done, and the lobbies are so arranged that the inside of the chambers need never be in contact with the outer air. Electric light is provided, and hydraulic lifts are used to take goods to and from the store on the upper floor.

On the west side of the dock, Nos. 1 and 2 transit-sheds are kept for general cargo and grain, and No. 3 transit-shed is used entirely for grain. Grain is also stored on the east side of the dock in some of the sheds, and there is a granary capable of holding about 25,000 quarters. New transit-sheds aggregating 800 feet in length and about 100 feet in width have recently been erected, and further additions are in progress.

The new granary, 319 feet long by 83½ feet wide with 7 floors, will contain 70,000 quarters of grain. The southern end of the granary is connected to the wharf-side of the dock by means of an overhead gallery, fitted with four conveyor-bands to carry the grain

from the conveyor-bands running along the wharf-side. From the four conveyor-bands in the overhead gallery the grain is thrown into four automatic scales, whence it falls to the bottom of the four elevators. The elevators lift the grain to the top of the building and discharge it upon four bands running in galleries for the full length of the building; and from these bands the grain can be thrown into a system of vertical shoots placed at close intervals over the floor-area. These shoots are arranged so that the grain can be intercepted and stored on any floor as required, and it can afterwards be drawn off through an opening at the floor-level, whence it falls down the shoot to the bottom-floor where it is sacked and delivered into railway-trucks as required. On the water-side of the dock, there are two grain-elevators, which discharge the grain from vessels to the conveyor-bands. One of these is driven by hydraulic-pressure water, and the other, which is not yet completed, will be driven by an electromotor.

In front of Nos. 1 and 2 transit-sheds openings are placed at intervals, so that the hydraulic cranes can lift the grain from the holds of vessels and discharge it into hoppers placed over openings in the verandahs through which the grain falls on to the conveyor-bands running below. There are altogether about 7,600 feet of conveyor-bands and 720 feet of elevator-belts. All the machinery recently supplied is electrically driven from the electric generating-station. At present there are 16 electromotors ranging from 2 to 18 horsepower.

The granary machinery is driven from an electric generating-station, in which provision has also been made for dock-lighting. The generating machinery consists of four gas-engines, three of 70 horsepower and one of 30 horsepower. The gas-engines drive, by means of belts, continuous-current dynamos working at 230 volts. The gas for driving the engines is obtained from a gas-producing plant, using washed anthracite peas. There are two sets of coolers, scrubbers and gas-holders.

There being no natural water-feeder to supply the place of water lost from the dock by leakage or by locking vessels in and out, centrifugal pumps are provided to maintain the level of the dock by pumping in water. A centrifugal pump, 24 inches in diameter, is fixed on the western side of the entrance-lock and another centrifugal pump, 30 inches in diameter, is erected on the eastern side of the lock. This pump is designed to discharge

2,500 cubic feet of water per minute to a maximum height of 28 feet; it is driven direct by a compound surface-condensing engine having cylinders 16 and 26 inches in diameter by 14 inches stroke, the maximum speed being about 170 revolutions per minute. There is an independent surface-condensing plant, and steam is supplied by two boilers, each 7½ feet in diameter by 12 feet long.

The floating pontoon-dock is 365 feet long and 85 feet wide, and, allowing for an overhang at each end, it is capable of taking a vessel about 410 feet long. It has a lifting capacity of 4,200 tons, and the dock itself weighs about 2,700 tons, including about 3 inches of water left in the tanks. It consists of six rectangular pontoons, 8½ feet deep at the centre, on which are bolted side-chambers and girders which serve the purpose of supporting the pontoons when submerged, of containing the pumping machinery and of connecting together the pontoons and distributing the stresses; any of the pontoons can be taken out and docked on the others for painting or repairs. Each pontoon is divided into eight compartments by bulkheads, and the pipes and valves are so arranged as to enable each compartment to be pumped out independently of the others. On the top of the side girders are placed the valves, etc., for manipulating the floating-dock. The pumping-machinery comprises four centrifugal pumps, each capable of discharging 1,000 tons of water per hour, four marine boilers each 6½ feet in diameter, and six small pumps for drainage and feed-water purposes. The mode of docking a vessel is as follows:—The dock is sunk so that the top of the keel-blocks may be about 1 foot or so below the bottom of the lowest part of the keel of the vessel to be docked, which is then floated into position on the dock and centred by means of ropes and shores. The pumps then discharge the water from the pontoons until the dock lifts the vessel from 6 inches to 1 foot out of the water, taper bilge-blocks are then drawn below the bottom of the vessel at each side, and serve to keep the vessel in an upright position and take the place of shores used in dry-docks. After this has been done, the pumps are again started, and the vessel is lifted, an operation which usually takes from ½ hour to 1½ hours, according to the size of the vessel. The dock is moored at the end to the quay-wall, and is secured sideways between dolphins placed one on each side at the centre and on each side at the outer end.

The machinery of the locks, cranes, capstans, etc., is worked

by means of hydraulic power. There are 14 hydraulic cranes and 3 others are in course of erection. The lifting power of the hydraulic cranes ranges from 30 cwts to 35 tons. The latter is a hydraulic coaling-crane, which can also be used for lifting heavy weights or boilers. This crane can be moved along the rails; a cradle to carry the coal-truck is provided, and is so arranged that it can be clamped to the top of the rails anywhere within the radius of the crane; the coal-truck is drawn up ramps on to the cradle by an hydraulic capstan; the cradle and truck are then lifted to a height sufficient to clear the vessel's bulwarks, etc., and then the load is swung over the hold and lowered as low down as possible; the crane then tips the coal-truck, lifting one end of the cradle, and the operation is complete. The crane can also be used for general purposes up to a weight of 35 tons.

POWER-HOUSE OF THE BRISTOL TRAMWAYS COMPANY, LIMITED.

The practical success of the early installation at Bristol has led the Bristol Tramways Company to undertake the electrical conversion of the tram-lines, which extend to about 50 miles. The central power-station, at St. Philip's Bridge, on the River Avon, is located advantageously in respect to coal and water. This station is equipped with the highest type of plant and machinery, an unique feature being that the engine-room is on the ground-floor, the boiler-room on the first floor, and the economizer-flue, feed-water tanks, and coal-bunkers on the second floor.

The engines are of the vertical cross-compound Corliss type, with cylinders of 22 inches and 44 inches by 43 inches stroke, running at 90 revolutions per minute, and each driving, direct-coupled, a 500 kilowatts electric generator. The fly-wheels are 16 feet in diameter, and each weigh 85,000 pounds. The steam-consumption of these engines is guaranteed not to exceed 12·7 pounds per indicated horsepower per hour, with a mechanical efficiency of not less than 92 per cent. The distribution is on the continuous-current principle, and the generators are of the 10 poles type, generating 1,000 ampères at 500 to 550 volts, as may be required.

The steel-frame building is 140 feet long, 52 feet wide and 93 feet in height from the basement to the roof-trusses; the basement being 9 feet in height; the engine-room, 37 feet; the boiler-

room, 20 feet 8 inches; with an additional floor above the boiler-room, 15 feet in height, to contain the water-tanks, coal-storage bunkers, economizer-flue, etc. A 25 tons electrically-driven overhead-crane traverses the length of the engine-room.

The boiler-room contains eight horizontal water-tube boilers, each with a capacity of continuously evaporating 8,250 pounds of water per hour, at a steam pressure of 160 pounds per square inch. Each furnace is fed by an electrically-driven mechanical stoker of the coking type, and the ashes are removed by the return-line of the conveyor, and received into a tank outside the building, whence they can be drawn into barges. The coal-supply is received from barges by automatic shovels, and delivered into a coal-storage tank at the back of the building, from which conveyers of the noiseless gravity-bucket type deliver the coal into the bunkers above the boilers, and thence the supply is drawn off for the furnace through weighing hoppers. The smoke-stack is erected at the end of the boiler-room, having a clear inside diameter of 10 feet, and being 200 feet in height above the foundations. It is built up of steel plates in rings, lap-jointed and rivetted, tapering upwards, and finished with an ornamental cap at the top. It is entirely self-supporting, and is lined throughout with fire-brick.

The economizer has 360 tubes in one group of 36 sections; and two feed water-tanks of 6,000 gallons each are placed on the floor above the boiler-room. The flue, which is built of steel plates, is also located on this floor: it is 70 feet long, and tapers from 4 feet to 12 feet.

The engine-room contains two lighting sets, consisting of two tandem compound high-speed engines, running at 400 revolutions per minute, and each driving, direct coupled, a 50 kilowatts, 500 volts lighting generator; and three motor-generators, each of about 40 kilowatts capacity, for use in connection with the rail-return.

There are two surface-condensers of the Admiralty type, each containing 3,200 square feet of cooling-surface and located on the engine-room floor. The air-pumps are of the vertical twin type, one set for each condenser. The circulating-pumps are motor-driven, 8 inches centrifugal pumps, one for each condenser. The condensing-plant and auxiliary steam-piping are located in the basement. The boiler feed-pumps are of the vertical compound duplex type, and are located in the boiler-room.

The hot-well consists of a cylinder, 96 inches long and 48 inches in diameter, located in the basement. The water from this hot-well is lifted to the water-tank on the economizer-floor by two electrically-driven pumps.

The switchboard is of white marble panels, 8 feet in height and 2 inches thick, bolted to angle-iron frames on a raised gallery, at the bridge-end of the engine-room. It consists of four generating-panels, two lighting generator-panels, three booster panels, sixteen feeder panels, one lighting-circuit panel, and one meter panel; all complete with instruments and switches.

The system, including the St. George and Hanham light railway, has an equipment of 250 cars, and has proved in its organization to be one of the most modern and complete system of electric tramways in the world.

THE BATH STONE-QUARRIES.

Bath stone, one of the best known and most extensively used building-stones, is obtained from the freestone of the Great Oolite, a member of the Lower Oolite formation, which latter is divided in descending order into:—(1) Cornbrash, about 16 feet; (2) Bradford Clay and Forest Marbles, about 91 feet; (3) Great Oolite and Stonesfield Beds, about 130 feet; (4) Fuller's Earth, about 122 feet; and (5) Inferior Oolite, about 80 feet.

The Great Oolite (3), in the neighbourhood of Bath, caps all the hills, which in some places, especially on the south, are completely honeycombed with old and modern workings, extending for miles underground, from which the stone has been quarried or mined. It consists of beds of shelly limestone and fine freestone, and may be divided into:— (1) Upper Rags, comprising coarse shelly limestone; more or less fine oolite-beds; and tough brown argillaceous limestone, varying from 20 to 55 feet; (2) fine Freestone, from 10 to 30 feet; and (3) Lower Rags, of coarse shelly limestone, from 10 to 40 feet.

The Freestone between the Upper and Lower Rags is the bed from which the building-stone is obtained. The stone, when first cut, is soft, and of a warm yellow colour, but it hardens and whitens much by exposure to the atmosphere and the evaporation of the moisture. It is stated that 1 cubic foot of Bath stone will absorb 1 gallon of water.

The spherulitic granules of which the stone is composed, when examined microscopically, do not present any organic structure, consisting merely of concentric films of carbonate of lime. The beds used for building-stone are not highly fossiliferous, though here and there mollusca and a stray fish-tooth may occur; on the Cotteswold Hills, the beds are rich in fossils, and the absence of organisms renders them easy to work. The beds which form the roof and floor of the workings abound in shells and corals.

The beds lie in an almost horizontal position, and the mining of the stone is carried on by underground workings extending for many miles in every direction, forming a perfect labyrinth. There are three distinct operations involved in removing the stone from its bed:—(1) The clearing out of a sufficient space for the insertion of the saw (the most laborious of the three); (2) the sawing of the stone down as many sides as possible; and (3) the "shaking" from their hold of those sides which cannot be got at by the saw. The getting of the stone is undertaken by gangs of men at so much per foot. Headings are driven off on either side of the main lines of direction, and certain headings are allotted to a gang of men, who work them out. Blocks are worked of as great a size as possible, but they are limited to some extent by the fact that the largest size which can be readily conveyed by rail is about 7 tons in weight. Blocks are readily obtained, however, containing from 90 to 200 cubic feet. The thickness of solid stone at the Box Quarries is about 25 feet.

CHEDDAR.

By E. H. COOK, D.Sc.

The picturesque village of Cheddar is situated on the warm southern slope of the Mendips, and enjoys a climate which is said to be fully a month earlier than that to the north of the range, only a few miles away. The village itself straggles along at the base of the limestone-cliffs which rise almost perpendicularly at the backs of the houses. From these cliffs, a magnificent view over the low-lying country to the south and west is obtained. This flat land, largely formed of the alluvial deposits from the rivers Axe and Brue, affords rich pasturage, and hence the district is

celebrated for its dairy produce; Cheddar cheese being known all the world over, and constituting the model upon which the fine American and Canadian cheeses are made.

The Mendip Hills are of comparatively slight actual height, but their effect as features in the landscape is enhanced by the fact that they rise so abruptly from the flats which bound them on the south. Geologically, the axis of the range is Old Red Sandstone, which comes to the surface at Blackdown, about midway between the northern and southern sides, at a height of about 1,000 feet. North and south of this, the slopes of the hills are formed of Carboniferous Limestone, and, as the hills have been subject to a considerable amount of denudation, there are abundant coombes and valleys, many of them of great beauty, running down the hillsides.

The Cheddar Gorge is one of these. From the village, the road winds between almost perpendicular walls of rock for more than a mile in its gradual ascent of the slope. The height of the rocks gradually diminishes as we ascend, but in some places is about 500 feet, the shapes being of the most fantastic kind. Although there can be no doubt that the gorge has been sculptured by the streams running down from the hills, at the present time it is quite dry. But towards the lower end a stream emerges from the base of the cliff, and forms a small river which runs through the village. It is certain that this stream has had a very considerable subterranean course before its emergence into the light of day, and this was accidentally proved some time ago by the poisoning of the stream by some works situated at a considerable distance away up in the hills.

Naturally in a range of hills composed largely of Carboniferous Limestone, caves and caverns are abundant. But the Cheddar caves are out of the common, because of the wealth of natural moulding in the form of stalactites and stalagmites which they possess. Enthusiastic admirers describe them as some of the most beautiful in the world, and it certainly would be difficult to find in so small a compass so many of the characteristic features of limestone-caves. The rate of growth of the deposit is not great; in fact, in one of the caves a stalactite and stalagmite whose ends are separated by a distance of about ½ inch are shown. No appreciable approach of the ends has taken place within the last 20 years. The caves at Cheddar have not yielded a large amount of

organic remains, but others in the neighbourhood have been very prolific. Thus at the Goatchurch in Burrington Coombe and at Wookey Hole remains of all the various animals usually found in cave-deposits have been discovered. Human skeletons were found in the Goatchurch caves, whilst implements and tools used by man are abundant in many of the cave-dwellings.

Some of the most interesting ancient remains in the district are those of the lake-village at Glastonbury, a few miles to the south. The period of the occupation of this village seems to have been just previous to the Roman invasion, and the numerous relics discovered indicate a very considerable advance in civilization.

Coming to more recent times it may be of interest to note that the country in which the Mendips are situated is one of the fabled districts of King Arthur and his Knights. For South Cadbury, a little distance away, is considered to be the site of "far-famed Camelot"; whilst King Arthur is supposed to be buried within the mouldering abbey walls of Glastonbury, where also Tennyson lays the scene of the search for the Holy Grail. It requires but little imagination to picture the Cheddar Gorge as the home of the famous dragon, and the stories of Malory acquire a deeper interest after a few days personal acquaintance with the district which we are describing.

When the Romans took up their residence in this country they were not long in discovering the mineral wealth of the Mendips, and carried on mining operations on a large scale. Some doubt has been expressed as to whether they worked for zinc, but lead was largely worked. Several pigs of lead have been found, as well as implements used in the varied metallurgical operations. The pigs when cast seem to have been carried over the hills to the Roman fleet lying in Uphill Bay or to a seaport in the Isle of Wight, and thence conveyed to Rome. It is an interesting fact that at the present day the waste-heaps left by these ancient metallurgists are being reworked for lead.

The district of Cheddar was used as a hunting-ground by the Saxon kings and also by some of the Norman monarchs. King Alfred was frequently in this neighbourhood, and a little to the west, at Battleborough near Brent, he defeated the Danes and compelled them to surrender their camp; whilst at a short distance to the south is the fabled scene of the incident with the neatherd's wife and the burning cakes.

ST. CUTHBERT'S LEAD-WORKS.

The process of treating the tailings left by the ancient workers is similar to that adopted by the St. Cuthbert's Lead Company for the treatment of the virgin material from the Warren, the extent of which is about 900 acres and leased from the Earl of Waldegrave. The material is worked in an open quarry and taken by tramways into the works, where it is placed in cylinders and disintegrated with the assistance of hot water, the rough material passing into a revolving table for hand-picking: the finer is distributed by classifiers into various automatic jiggers and on to a number of Wilfley tables which have recently been substituted for the old-fashioned round buddles. The Wilfley tables are arranged in double series, that is half the products of an upper table are reconcentrated on a lower table. This plan was specially introduced to enable the fine slimes to be caught at one operation, and is answering very well. The tailings are carried in a launder and deposited some distance away from the works, the water being allowed to gravitate back to the pumping-station and, being cleansed by its travels, is used over again. The galena is sold in its natural state to smelters. The carbonate of lead is briquetted and smelted in a water-jacketted furnace, of a type specially calculated to treat such material, with the slag left by the old workers which invariably carries in it a payable quantity of lead. The smelted lead is run into ingots in the usual way. The furnace is served with a blower having a separate steam-engine to drive it. Considerable alterations and improvements have been made in the plant, and not the least item of interest is the general use of Australian jarrah wood for all purposes where strength and durability are required.

During the inspection of the accumulations of lead débris at the St. Cuthbert's works by the members of The Institution of Mining Engineers, Mr. James McMurtrie, of Radstock, who is agent for Lord Waldegrave and other owners of lands within the Mendip district, exhibited to the members an extremely interesting ancient plan on vellum of the mineries, and he also read from an old book* a few of the laws and customs that regu-

* In the Mining Record Office, London, there is a fac-simile of an old document reciting the laws of the Mynd Deeps of the Mendip Hills.

lated the mining, dressing and smelting operations during the seventeenth and eighteenth centuries. Some of the customs were curious and others amusing. Mr. McMurtrie stated that according to this record as many as 10,000 miners and others were, at one period, employed chiefly upon the lead-industry within the Mendip area, and that the Chewton Warren was largely dug over to some depth for lead-ore during the last two centuries.

During an inspection of the St. Cuthbert's works by the members they were informed that the modern concentrating plant, newly erected, had greatly reduced the cost of concentration, besides achieving closer work than could be effected by the buddles, now discarded; but that such is the buoyancy of some of the float-lead that even with the present tables and vanner there is rather too much loss to be entirely satisfactory, and that further arrangements for diminishing it are being considered. The supply of hot, instead of cold, water to the revolving disintegrating-drum had greatly facilitated the pulping of the material. This improvement had been instituted by Mr. Jones, the manager. The modern blast-furnace was being blown in at the time of the members' visit. Jarrah wood had been extensively employed at the works. The tramroad sleepers made from it were admirable and are expected to be very durable.

NOTES ON THE FOREST OF MENDIP, ITS MINING CUSTOMS AND ANCIENT LAWS.

By J. McMURTRIE, F.G.S.

In Mr. Thomas Morgan's "Notes on the Lead-industry of the Mendip Hills" he has stated that this "ancient occupation," which dates from the days of the ancient Britons, was followed during the lengthened period of the Roman conquerors; pigs of lead bearing the names of the Roman emperors, gold ornaments, and other remains having been found at Charterhouse and elsewhere amongst the lead-workings on these hills, which were crossed in various directions by Roman roads. Some pottery of that period had been exhibited to the members by Mr. Jenks, which presented the usual features characteristic of those early days.

Of the period which followed the Roman occupation, when the Roman was followed by the Saxon, and the Saxon by the Norman, little was known; but in the latter period the castle of Richmond or Richmonte, the ancient manorhouse of East Harptree, a place of considerable strength and importance, was founded on the northern slope of the Mendips, and in the year 1138 it was held by Sir William de Harptry against King Stephen, who captured it, the King in person leading the assault.

At an early date Mendip was a Royal Forest, and ancient documents in the Public Record Office state that various adjacent vills were afforested in the reign of King John and added to the King's Forest of Mendip, but in the course of time these, like many similar afforestations, were declared to be illegal, and with a view to reducing them within their ancient and lawful boundaries, a perambulation was made of the forest on May 10th, 1298, when it was found that certain of the additions were illegal and ought to be disafforested.*

Between 1301, in which year the above perambulation was confirmed by the Sovereign, and the reign of King Edward IV., an extensive grant of rights, liberties and privileges within the portions of the Forest of Mendip adjoining their respective

* Leland in his *Itinerary* gives another account, and mentions that the forest "was well furnished with dere; but anon after riots and trespasses done in huntynge it was disaforestyd."

manors or lordships was made by the Crown to the Bishop of Bath and Wells, the Abbot of Glastonbury, the lord of the manor of Chewton and the lord of the manor of East Harptry, who then resided at his castle of Richmount or Richmond closely adjoining to the Royal Forest, the grant being of so important a character that the four recipients thereof came to be commonly known in those parts as The Four Lords Royal of Mendip. The accompanying plan (Plate XXII.) is a facsimile on a reduced scale of a map of unknown but very ancient date, drawn on a skin of parchment, now in the possession of Earl Waldegrave, as lord of Chewton and East Harptree or Richmond.* It shews the ancient boundaries of this Royal Forest, together with the roads which passed through it and the churches, manor-houses and other ancient buildings by which it was surrounded.

On the margin of the skin will be found a rude representation of a huntsman with dogs in pursuit of what is presumably a fox, thus recalling the early pastimes of the Forest; and within its precincts are indicated several mineries or lead-works, which were established on these hills, including Priddy minery and Chewton minery, where The Institution of Mining Engineers had met, also the West minery, near Charterhouse, and the Harptree minery, which were no longer in operation. It would thus appear, that each Lord Royal had a chief minery for the dressing and treatment of ore within his own territory, the large deposit of slags and slimes found at these mineries not being the result of mining carried on in their immediate vicinity, but the residuum from ore brought from other parts of the hill. The position of these chief mineries as well as smaller dressing-places found elsewhere, was doubtless due to the presence of a water-supply, a scarce commodity in this upland country, which, notwithstanding its heavy rainfall, is practically a streamless area, the land-drainage disappearing down "swallets" into the rock beneath, whence it finds exit at the base of the hills as at Wells, Wookey, Cheddar and Chewton.

The existence of these mineries was also due probably to the fact that there were no great mining-companies in those early days, each with its own works to manipulate the ore raised, the

* A facsimile of another copy of the same map in the Mining Record Office faces page 134 of *British Mining*, etc., 1884, by the late Mr. Robert Hunt. There is also an interesting notice of another copy of the same map on page 134 by Mr. Thos. J. Pearsall; and on pages 135 and 136 is a copy of "The Lawes of the Mynedeepes" from the first-named map.

mining being carried on for the most part by the workmen themselves, or by very small companies of them, who, having discovered and worked a lode within certain ground to which they had claim, had apparently to remove the ore to the general minery to be dressed and smelted, when the Lords' officer claimed his "lot" or royalty of one-tenth part.

To what extent mining was carried on during the period of afforestation there is nothing to show, but it is evident that under the grant already referred to and within certain parts of the Forest, the four Lords Royal thenceforth exercised certain rights consisting of royalties, liberties and privileges, with power to have their own laws, courts, officers and juries, and that the mining-industry gradually became of considerable importance.

In the course of time, the laws and regulations of the four royalties or liberties of Mendip, so created, were reduced to a code under circumstances set forth in the preface to the Mendip minery laws, and this code, of which official copies were kept for the use of each court, appears to have been in constant use down to the early part of the nineteenth century.

In the map of the Forest already referred to and on the right-hand margin, the first 10 "orders" or laws are set forth,* from which it might be inferred that this skin formed or was intended to form part of a roll to contain the entire code. But only this one skin had been found amongst the papers of the Waldegrave family. These laws, which are very much in accordance with those once in force in the Peak district of Derbyshire and in the Stanneries of Cornwall, are interesting mining relics of the past.

The code belonging to the lordship of Chewton, of which a copy is printed at the end of these remarks (Appendix II.), is probably amongst the earliest examples of mining laws in force in this country.

The introduction to the "orders" is of interest, and is followed by Nos. 1 and 2 orders, relating to the conditions of license under which workmen were allowed to carry on their occupation within the territory of the Lords Royal, without which license and sureties for good behaviour their work was liable to forfeiture, as provided in No. 7 order. No. 3 order provides that two courts were to be held yearly, such courts being constituted by calling the lead-miners together and electing a jury of twelve from their number,

* These orders, which are not reproduced on the plan, are printed in Appendix I.

while No. 4 order provided for "three manner of arrests" which such courts had power to make. No. 5 order defines the claim to which a workman was entitled on the discovery of a lode, namely, to as great a length of it (presumably in each direction) as he could throw his hack, standing in his pit, to his girdle or waist, another order giving him a right to 100 feet on either side of the lode; such claims being spoken of elsewhere throughout these orders as "pitches." No. 6 order is directed against slothful working, and a subsequent order provides that a claim not exercised for one year may be transferred to others. Many of the orders (such as Nos. 8, 13 and 14) were designed for the protection of the lord's rights, for preventing the carrying of ore from one lord's land to another, for ensuring that the ore raised within his territory should be duly accounted for and the "lot" or royalty paid.

In these days, when Mines Regulation Acts follow each other in rapid succession, both masters and men are apt to complain of the strictness of the laws under which they live, but nothing in these days approaches in severity to Nos. 17 and 33 orders relating to the burning* of felons within the boundaries of the Forest of Mendippe. To what extent this burning was intended to be carried it is impossible to say, but it is clear from the context that neither death nor permanent disablement can have been contemplated, otherwise there would have been no need to make provision against a second offence.

It is interesting to note No. 18 order for the recovery of dead bodies, and to remark that there is nothing at all corresponding to it in the mining legislation of modern times, although many instances can be recalled of colliery-disasters in which the bodies have never been recovered. One inference may be drawn from the depth named in the order, namely, that it was no doubt an extreme depth in the days to which it refers, possibly a depth rarely if ever reached.

It is obvious from No. 62 order, and other references to the same subject in the code, that the use of fire in driving through hard ground was a common practice long before the days of "permitted explosives," and it is interesting to notice the regulations considered necessary for its use.

* "Burnt, burned: impressed by burning or branding; branded. 1652, *Advt.* in *Proc. Parliament*, No. 163, A Browne bay Mare . . a burned O upon each hip"; *A New English Dictionary on Historical Principles*, edited by Mr. James A. H. Murray, 1888, vol. i., page 1195, first column.

No. 83 order relating to timbering appears to reverse the present state of things, its object being not the protection of the workmen's lives by the officials, but to safeguard the officials' lives through the workmen.

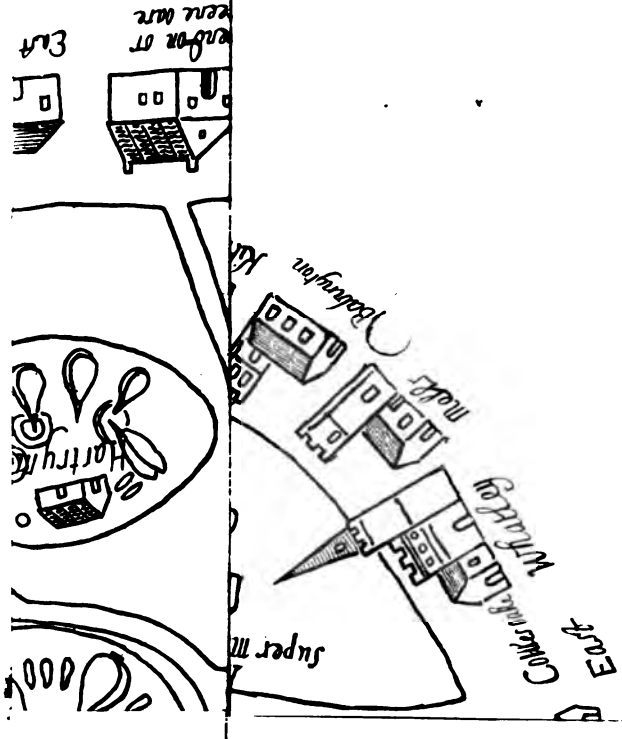
Lead and iron were probably the earliest products of these hills, but there appears to have come a time when calamine or zinc-ore, and ochre came to be worked, and in order to make the laws of Mendippe applicable to these later discoveries and to ensure the lord's right to his "lot" or royalty thereon, No. 105 order was duly passed on November 25th, 1773, and confirmed on the next court-day.

Such are a few of the more striking examples from the ancient "Orders and Customes" of these hills, but as will be seen from the "Table" or index the subjects dealt with were of a very varied and comprehensive character, and for conciseness and clearness they will compare very favourably with the work of the parliamentary draughtsman in more modern legislation. There are regulations to prevent the buddling and dressing of ore in those months of the year when cattle were turned out to graze on the hills, because "many cattel are hurt and killed" (No. 20); others were directed against those who "strike and draw bloud," for which the penalty was £5 (No. 25); and against the use of "approbrious words," for which the penalty was £1 (No. 34); and there was an order against buying or selling ore at Mendippe on Sundays or holy-days under a penalty of 40s. (No. 50). There are orders relating to the fencing of openings (No. 9), the proper timbering of mines on special occasions, if not generally (No. 83); and as to stopping "ruinated holes" dangerous to man and beast (No. 88).

The last order in the book, passed in 1774, seems to have been in the nature of a mines-drainage scheme, and may be taken as an indication that mining had reached a depth where water had become troublesome, for it gave power to a company of adventurers to drive an adit, with authority to levy dues on all mines drained thereby.

About the beginning of the nineteenth century, the busiest period of the mining-industry seems to have come to a close, but the working of lead, iron and calamine have been carried on at intervals down to our own day, and present appearances at St. Cuthbert's point to further development in the near future.

Notes on the



APPENDIX I.—THE OLD AUNCIENT CUSTOME OF THE OCCUPACON OF THE MYNEDRIES IN AND UPON THE KINGS MA^{TIES} FFORREST OF MEYNDEEPE WTHIN HIS MA^{TIES} COUNTY OF SOMSETT.*

BEE IT RIGHT WELL KNOWNE That this is enrolled in the Kings Highnesse Exchequer by the time of King Edward the fourth of a great debate that was in the County of Som^{r}set Betweene the Lord Bonvills Tenants of Chuton and the Prior of Greene Oare the said Prior complained unto King Edward of great Injuries and wrongs that hee had upon Meyndeepe being the Kings fforrest The said King Edward comanded my Lord Chocke being Chiefe Justice of England to goe downe into the Countrey of Meyndeepe and sett a Concord and peace in the countrey upon Meyndeepe upon paine of his high displeasure The said Lord Chocke sate upon a place of my Lord of Bathes called the fordge upon Meyndeepe where hee comanded all the Comoners to appeare there and in especiall the foure Lords Royall of Meyndeepe THAT IS TO SAY my Lord the Bishop of Bath and Wells my Lord of Glastenbury my Lord Bonvile Lord of Chuton and my Lord of Richmond wth all the appearance to the number of tenn thousand people A Proclamacon was made to enquire of all the said Companie how they would bee ordered Then they all wth one assent made answer and said That they would bee ordered and tryed by the foure Lords Royall Then the foure Lords Royall were agreed That all the Comoners of Meyndeepe dwelling in theire Tenements being wthin the bounds of Meyndeepe should turne out theire Cattle att theire outletts as much the Summer as they bee able to keepe the Winter wthout hounding or pounding upon whose ground soever they went to take theire course and recourse To this the said foure Lords did put theire Seales And alsoe were agreed that whosoever should breake any of these bounds should forfeite to the King one thousand Markes and all the Comoners theire bodyes and goods att the Kings pleasure that doth either hound or pound.

IRROT: in Scco^{r} Dñæ Reginæ.†

THE OLD AUNCIENT custome of the occupacon of the Mynedries in and upon the Kings Ma^{ties} fforrest of Meyndeepe wthin his Ma^{ties} County of Somsett being one of the foure Staples of England w^{ch} hath bene exercised used and continued through the said fforrest from the time whereof man now living hath noe memory is as hereafter doth particularly ensue:—

1. FIRST That if any man whatsoever hee bee that doth intend to venter his life to bee a workman in the mynedery Occupacon hee must first of all require Lycence of the Lord of the Soyle where hee doth purpose to worke or in his absence of his officer as Lead Reve or Bailye and the Lord nother‡ his Bayliffe or officer can deny him.

2. ITEM that after the first Lycence had the workmen shall never need to aske leave againe but to bee at his freewill to pitch within the said fforrest and to breake ground where and in what place itt shall best like him to his behoofe and profitt using himselfe justlie and trulie.

* These are the ten orders as engrossed on the vellum map, which is reproduced as Plate XX.

† *Irrot: in Saccario Dominæ Reginæ*, "Enrolled in the Exchequer of our Lady the Queen."

‡ Neither?

3. ITEM That every man that doth begin his pitt or Groove shall have his hack throw two wayes after the Oare;* And note that ..ee that doth throwe the hack must stand in his said Groove to the girdle or wast And then noe man shall or may worke wthin the Compasse of his said hacks throw.

4. ITEM That when a workman hath landed any oare hee may carry the same to clensing and blowing to what minedrie hee shall please for the more speedy making of the same soe that hee doe trulie pay the tenth thereof to the Lord of the soyle where itt was landed.

5. ITEM that if any Lord or his officer have once given Lycence to any man to build or sett upon any Hearth or washing house to wash and cleanse and blow theire oare hee who hath soe once leave shall for ever keepe itt sell itt or give itt to whome itt shall please him soe that he doe trulie and justlie pay the Lott Lead w^{ch} is the tenth pound that shall bee blowne att the same Hearth or Hearths And alsoe if hee doe keepe itt tenantable as the Craft doth require.

6. ITEM that if any man of that occupacon doe pick or steale any Lead or Lead oare to the value of xiii^{d} the Lord or his officer may arrest all his Lead and oare house or hearths wth all his Grooves and workes and keepe them as a forfeit to his owne use And shall take the person that soe hath offended and bring him where his house or worke and all his tooles and Instruments belonging to the same occupacon bee and put him into his house or worke and set fire in all together about him and banish him from that occupacon before all the Myneders for ever.

7. ITEM That if ever that person doe pick or steale there any more hee shall bee tryed by the Comon law, for this Custome and law hath noe more to doe wth him.

8. ITEM that every Lord of soyle or soyles ought to keepe two Mynedrie Courts by the yeare and to sweare twelve men or more of the same occupacon for the . . ders† of all misdemeanours and wrongs touching the Mynedries.

9. ITEM the Lord or Lords may make three manner of Arrests (That is to say) the first is for strife betweene man and man for theire workes under the earth. The second is for his owne dutye for Lead or oare wheresoever hee find itt wthin the said fforrest, The third is upon felons goods of the same occupacon wheresoever hee find itt wthin the same Hill.

10. ITEM That if any man by the meanes of this doubtfull and dangerous occupacon doe by misfortune take his death as by falling the earth upon him by drowning by stifleing wth fire or otherwise as in times past many have bene The workmen of this occupacon are bound to fetch the body out of the earth and bring him to Christian buriall att theire owne proper Costs and Charges although hee bee threescore fathom under the earth as heretofore hath bene seene And the Coroner or any other officer att Jurye shall not have to doe wth him nor them.

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* Rake?

† Redress?

APPENDIX II.—THE ORDERS AND ANCIENT CUSTOMES OF THE OCCUPACŌ AND CRAFT OF THE LEAD MINERS WORKING IN AND UPON THE OLD DISAFORESTED GROUND CALLED MENDIPP IN THE COUNTY OF SOMERSET.*

Be it Right Well Known, That this is enrolled in the Kings highness Exchequer in the Time of King Edward the fourth† of a great debate that was in the County of Somerset, Between the Lord Bonvills Tennants of Chewton, and the Prior of Green Oare, the said Prior complained unto King Edward of great injuries and wrongs that he had upon Mendip; being the Kings fforest: The said King Edward commanded my Lord Chock,‡ being Chief Justice of England to go down into the County of Mendip; and set a Concord and peace in the County upon Mendip upon pain of his high displeasure. The said Lord Chock sate upon a place of my Lord of Bathe's call'd the ffordge upon Mendip, where he commanded all the commoners to appear, and in especial the four Lords Royall of Mendip, that is to say, my Lord the Bishop of Bath and Wells, my Lord of Glastenbury, my Lord Bonvill Lord of Chewton, and my Lord of Richmond, with all the appearance to the number of Ten Thousand people. A Proclamation was made to enquire of all the said Company how they would be ordered, Then they all with one assent made answer and said, That they would be ordered and tryed by the four Lords Royall, then the four Lords Royall agreed, That all the Commoners of Mendip dwelling in their Tenements being within the bounds of Mendip should turn out their Cattle at their outletts, as much the Summer as they be able to keep the Winter, without hounding or pounding upon whose Ground so ever they went, to take their course and recourse. To this the said four Lords did put their Seals. And also were agreed that whosoever should break any of these bands, should forfeit to the King one Thousand Marks, and all the Commoners their bodies and goods at the Kings pleasure that doth either hound or pound.

TABLE.

	Order.
To crave Licence	1
Licence once had shall never need more	2
Two Minery Courts Yearly	3
Three arests	4
The Hack's throw	5
Sloathful working and detracting of time	6
Good behaviour	7
For deceit of the Lord	8
For covering and stopping of Grooves	9
Works unwrought	10
Working in Sev[ll] grounds	11

* "The laws of the miners were printed at London, 1687, 12mo." *The History and Antiquities of the County of Somerset*, by the Reverend John Collinson, 1791, vol. ii., page 117.

† 1461 to 1483.

‡ Sir Richard Choke was created a justice of the common pleas, September, 1461, *Dictionary of National Biography*, 1887, vol. x., page 267.

	Order.
Breaking of bargains	12
For carrying of Oare out of the Minerie	13
Licence to carry Oare out of the Minerie	14
Tuesdays and Fridays weighing days and no other	15
Stock and Tally	*ibid.*
Letting of Hearths and Houses	16
Burning of Thieves and Felons	17
Burying of dead bodies and to make Ordinances	18
An order to pitch and find the Chine	19
For Budlers in Widmore	20
To prosecute within three weeks or else to be void	21
He that is found guilty to pay Six Shillings & eight pence	22
Entering and carrying by force	23
Breach of Arests	24
To strike and draw blood to lose five pounds	25
To Arest before five Fathom deep or else to be void	26
Entring of Bargains	27
Giving of Oare in pieces, and Lead unweighed	28
To Sell more than he can justifie	29
Letting forth of parts before 5 Fathome deep	30
For budling in the Minerie	31
For entering Grooves privily to know the Secrets	32
For burned and banished men	33
For approbrious and unseemly words	34
Carrying of Lead and Oare unweighed & unmarked	35
No weapons but working Tools	36
No taking under Colour of Title	37
Resisting of the Lords Officers	38
Entering into Grooves after verdict is given	39
Officers to pay for neglect of their Office	40
Goods arested not to be moved	41
An Order for the Sumoning or warning of the Minie Jury	42
An Order for levying amercements	43
Default between Court and Court	44
For those that intermeddle with burned & banish'd men	45
For levying Executions given by verdict of Jury	46
Fails for lott Lead	47
No man shall weigh Lead, but in the p'sence of an Officer	48
No man shall carry Lead before it be parted	49
For buying Oare on Sundays and holy days	50
Unlawfull Grooves or holes	51
For them that break, or Steal draught Stillions	52
An Order for Hacks throwe	53
An Order for payment of wages and Charges	54
An Order for odd-ground and Catches	55
For pawns	56
Seaven Feet	57
The Law Hack detained, throwing the Hacks in due time, and who ought to throw the Hack	58
An Order to restrain foreign Suits	59
An Order for those that find and sell Goods, and not to sell before he make the Lead Reeve acquainted	60
An Order for the Minerie	61

	Order.
An Order for laying of Fires	62
For budling in Rush Meere	63
For petit Jurys to yield their verdict in fourteen days	64
An Order for the Confirmation of the books indented	65
An Order for the giving of pitches	66
An Order for the meeting of the Minery Jury	67
None to fetch Oar under the Earth after it be made known	68
When two Grooves be Struck togeth^{r} they cease working	69
An Order against all false Oaths	70
Against all Oare under Colour a little beyond the bounds	71
The 69th Order Confirmed and made more plain	*ibid.*
An Order for Grand Jurys to Stand in from Court to Court	72
An Act for Cobling of Oare	73
For entering Orders in this Book before they have given their sev^{ll} p^{r}sentments	74
By those that keep halfmen and other Servants Shall enter their Names in the Store Bailiff's Book	75
For Grooves when they are Strucken together to cease working	76
Pitches lawfully made to stand twelve months	77
Allowed by a Succeeding Grand Jury	78
An Order for producing of Witness	79
Concerning parts to the Shore	80
For prolonging and detracting of Suits	81
For aresting in the Lord's name, & not to make his matter good	82
For making Grooves firm for Plumbers	83
Imbezeling and detaining the Law Hack banish^{mt}	84
For Pitches to stand twelve months and a day	85
For Cobling of Oare	86
For altering the List of Jurymen's names after they are returned... ...	87
For Stopping of Ruinate Holes	88
For the Plaintiff for taking up his Fees being once put into the Lead Reeve's hand	89
For carrying the water in Row Pitts to the maine Stream	90
For the Officers Fees	91
For Jury's Fees upon a Summons	92
For drawing the water at pucksuds	93
For giving y^{e} Lords Officers an Accoût of what Oare they make out ...	94
A new Order concerning striking of Grooves together & odd Ground ...	95
For Summoning a Jury to forfeit twenty Shillings	96
An Order for M^{r}. Bushell's water work in Row pitts	97
An Order for what Causes a Jury ought to be Summoned confirmed ...	98
An Order impowering Lead Reeves to S:mmon Plaintiffs and Defend^{ts} ..	99
An Order against Such as pick and Steal Oare	100
Small Pitches to Stand 12 months and a day & no long^{r}	101
The same Order confirmed	*ibid.*
A new Order concerning Pitches	102
Elder Pitcher to strike to y^{e} Younger	103*

* There are other orders not included in this table, as follows: No. 103, concerning unwrought pitches; No. 103, elder pitcher to strike to any younger pitcher; No. 104, is an order for the confirmation of the orders contained in the MS. book, from which these have been printed; No. 105, concerning calamy, etc., and confirmed; and No. 106, for the more effectual draining of the deserted lead-works at Row Pitts and Green Oar.

A COPY OF THE MYNRALL JURYS OATH OF CHEWTON MANNER.

You shall Dilligently inquire and true presentments make, of all such things as you shall be Charged with for the service of the Lord of this manner; Inquirable att this Mynrall Court. You shall truly Examine all Abusses and Offences Committed, or done by any workman against the Laws and Customs of this Occupation; you shall allso truly and Rightly Examine and try all Abusses and Contraversses Conserning the Occupation as shall Come before you according to your Evidence, and in all things Uprightly Behave your Selves as well Betwen the Lord and workmen as Between workman and workman; and make true presentments thereof According to the Antiant Customs of the Occupation, and orders of the hill within this manner of Chewton, and in all other things belonging to the Articles of your Charge as God shall help you and by the Contents of this Book.

CHEWTON: Hereafter Followeth the Orders and Ancient Customes of the Occupacõ and Craft of the Lead Miners working in and upon the Old disaforested Ground called Mendipp in the County of Somerset, now divided and delivered unto Four Lords Royal, being reputed and taken amongst the Said Miners, as one of the four Staples of England, which hath been exercised and continued, throughout the Said disaforested Ground called Mendipp, from the time whereof man hath no memory; together with certain good and laudable Customes and Ordinances, agreed, ordained, and renewed, or made at the Minery Court of Sr Edward Walgrove Knight, one of the Four Lords Royal of the Said disaforested ground holden at his Mannour of Chewton under Mendipp aforesaid, the Tenth day of July,* in the Second Year of the Reign of our most Sovreign Lady Mary, by the grace of God of England France and Ireland Queen &c.

For as much as the Said Miners and Workmen upon the Said Mineries, there before this time, have claimed Customes to and for their Occupation, in and upon the Said disaforested Ground, and amongst themselves, to be observed, and kept, having no ancient writing, or prescription of Antiquity, to be shewed for the Same, So that for lack thereof their Said Customes were altered, Changed, and used amongst them divers and Sundrie ways, whereby no little contention, Strife and debate hath of late been erected and moved, for appeasing thereof it is fully concluded, determined and agreed, that all and Singular Such Ordinances, hereafter ensueing, Shall from henceforth be deemed, taken, holden, reputed, judged and Stand for ancient Customes to the Said Mineryes and workmen within the Said Mineries to be observed and kept for ever. And for the perfecting, and full concluding of the Same, it is also concluded and agreed, that the Same Ordinances Shall remain in Writings Indented, whereof the one part to be in the Custody and keeping of the Said Sr Edward Walgrove and his Heirs, and the other part to be permanent, and remain in the custody of the Tenants and Inhabitants of Chewton, to the use of the Said Miners, and Workmen for ever.

1. *To crave Licence.*—First if any man whatsoever he be that doth intend to work, and venture his life to be a man of this Occupation he must first require Licence of the Lord of the Soile where he doth purpose to work, or in his absence of his Officers called ye Store Bailiffe, or Lead-Rieves, for the time

* 1554.

being, putting in Sureties to observe the Customs of the Miners. The Lord nor his Officers ought not to deny him, without lawfull cause, the party being of good name and fame.

2. *Licence once had shall never need more.*—ITEM that after such Licence once obtained, the party Shall never need Licence more, but at his Free will to pitch, & break ground, within the Same Lord's Soile, where, and in what place he shall think best himself, for his behoof and profit, using himself justly & truely, according to the Occupation.

3. *Two Minry Courts Yearly.*—ITEM the Lord of every Soile upon Mendipp aforesaid, ought of right to keep two Several Minerie Courts in the Year, calling the Lead Miners together, with their Copartners and workmen, and to Swear twelve, or more of the worthiest according to the Nature of the precept, for the good administration of Justice and observation of the ancient Customes, and for redress of all misdemeanours concerning that Occupation.

4. *Three Arrests.*—ITEM that the Lord, and Lords of every Soile may lawfully make three manner of arrests (that is to Say) the first for Strife between man and man, for their works, or Grooves under the earth, the Second for his own duty for Lead, or Oare, or anything thereof coming wheresoever he find it, within Mendipp afors^{d}, y^{e} third is for and upon the Seisure of all Fellon's goods, of the Same Occupation forfeited, wheresoever it be found within the Said disaforested ground, or any part thereof.

5. *The Hacks throw.*—ITEM if any workman fortune to have Oare a Land, out of his Pitt, or groof, and before any other workman begin any other pitt, then no other man shall begin within the compass of the Hacks throw of the Same workman So having Oare a Land, So that the Said workman Set in Competent workmen to work the Same throughly. Provided that Such workman, having Oare a Land, and claiming his hacks thowe, must Stand to the Girdle, Stead, or Waste in his Pitt, or groove when he shall throw, by the law of y^{e} Occupacō.

6. *Sloathfull working & detracting of time.*—ITEM if any workman, or workmen, having a groove do Sloathfully work, detracting of time, when other men do labour whereby other men have the greater pain in their water drawing, after complaint made, and warning given, by the Store Bailiffe or Lead Reeves, or by either of them, then it shall be lawfull to the Said Officer, or Officers, to Sease the Said work into the Lord's hands, and to expell Such workmen, detracting the time (as is aforesaid) and to Set in others, to work y^{e} Same and to answer the Lords their profitts.

7. *Good behaviour.*—ITEM if any workman do work before he hath obtained Licence, and put in Sureties to the Officers, for his good behaviour during his abode in work, and to pay Such duties and amercements as shall be Seased on him, then Such work to be forfeited to the Lord.

8. *For deceit of y^{e} Lord.*—ITEM if any workman, whatsoever he be, doth not truly, and duely lot and pay unto the Lord his very Just duty of Oare, and Lead, & of all things rising and growing of y^{e} Same, or doth unjustly Sell the Lord's Lott, of what kind soever it be, to the intent to defraud and deceive

the Lord, then Such person, & persons, to forfeit all Such work, & works as he or they have, and be banished the Occoupcō for ever by Such punishment, as Shall be adjudged by the Order of the Court, information, and presentment, according to the Law of the Occupation.

9. *For covering & Stopping of Grooves.*—ITEM that all manner of men, having Groove, or Grooves, Shall from henceforth keep the Same Sufficiently covered from time to time, upon pain to forfeit 6ˢ. 8ᵈ. for every time, and also if any man do Suffer his pitt, or grove to ly open, unfilled, or unstopped by the Space of Eight days next after, that he or they have taken the perfection of the work, & left working in the same, then to forfeit to the Lord (if the Same be not well and Sufficiently Stopped) twenty Shillings, for every Such Pitt, to be levyed of the Mineral Goods and Chattels, of Such Offender or Offenders, without any further assurance, or Seassing in Court.

10. *Works unwrought.—This Order made void.*—ITEM if any workman, or workmen do permitt, and Suffer, the work, or works, of any of them to ly unwrought, by the Space of one whole Year, and do not revive, or renew yᵉ Same, if weather and Year will Serve So to do, then the Store Bailiffe or Lead Reeves to warn him or them that owe Such works, to come and See the Same work, or works renewed, and wrought, and if the parties refuse So to do, then after Such denial, it Shall be lawfull for the Lord, and his Officers to Licence and appoint other workmen to work the Same, untill he be appointed and Licenced by the Lord's Officers.

11. *Working in Sevᴸ grounds.*—ITEM that no manner of persons shall begin any work, or grove, within any Several Grounds, holden of the Lord of this Mannour without Special Licence of the Lord or his chief Officer, and that under writing and by Warrant for yᵉ Same.

12. *Breaking of bargains.*—ITEM that no workman Shall break his bargain, or promise that he Shall make, concerning the Sale of his Lead, but Shall from henceforth truely, and justly keep, and perform his promise, and in no-wise Shall sell neither Oare, nor Lead to any other person, untill he have fulfilled his first promise and bargain, upon pain to forfeit to the Lord One Hundred of Lead. And it shall be lawfull unto the Store Bailiffe, or Lead Reeves, and to either of them by vertue of these Ordinances, to Arest, Stay, and destraine all Such goods and Stuff, as the Offender, or Offenders Shall have, in and upon, the Said Ground and Minerye, and the Same to detain untill he have paid his Forfeiture, and also Satisfyed his former promise and bargain.

13. *For carrying of Oare out of yᵉ Minerie to forfeit five pounds.*—ITEM that no manner of person, or persons, shall from henceforth, carry out of the Minerye any Oare, being raised, or mined within the Precinct, and Soile of the Lord of this Mannour, of Chewton (aforesaid) nor any thing that thereof arise, as Brocks, Tayles, Bowsheaps and Such like, to any other Minerye, to Smelt, or convert and make into Lead but only to work, wash and convert, Smelt and make into Lead all the Said Stuffe, at the Said Minerye at Chewton, and not elsewhere, upon pain of every person So offending to lose Five pounds, to the Lord of the Same Soile, So that the Said Oare, and Stuffe may conveniently be washed, converted, smelted and made into Lead, within the Said Minerye of Chewton.

14. *Licence to carry Oare out of the Minerie.*—ITEM if any workman, at any time hereafter, shall have occasion to occupy, & convert, Oare, or Stuffe that is in the Mynerie aforesaid, and that the Said Minerie is not then presently able to make the Same for want of water, convenient Leisure, or any other insufficient cause to wash, Smelt & convert y^e^ Same, then it Shall be lawful to all Such person, and persons (having Such haste and need,) first to come unto y^e^ Store Bailiffe and Lead Reeves declaring their Need, and to put in Sureties for to answer the Lord his duty, as well of the Lott Lead, as also of Brocks, tayles, flight, and bowsheap coming of the Same, and also to bring again the Lott, and Lord's duty of all the p^r^mises into the Said Minerie of Chewton, and there to make true delivery thereof at their own proper costs & charges. And this agreement had & made, then to carry their Oare, and Stuffe to what Minerie they Shall think good, and if any person Shall do contrary to this Order, then to pay Such Fine as is set down in the Order before mentioned.

15. *Tuesdays and Fridays weighing days, and no Other.—Stock and Tally.*—ITEM that henceforth no manner of person, Shall weigh Lead, without the Store Bailiffe or Lead Reeves be present w^th^ their Stock and Tally, and there to Stock, and Tally it. Also it is agreed that the weighing days, shall be Tuesdays & Frydays, and on no other days, at the which days the Store Bailiffe, or his Deputys and y^e^ Lead Rieves, or one of them to give attendance, upon pain to forfeit every day Twelve pence. Also one Score and Tally to be between y^e^ Workmen and the Reeves, and y^e^ Reeves to keep the Stock, & t'other y^e^ Tally for the whole number, to be between the Reeves and y^e^ Store Bailiffes, to keep a book for y^e^ whole and perfect account, and reckoning to be made at every Minerie Court.

16. *Letting of Hearths, & Houses.*—ITEM that if at any time hereafter the Lord, or his Officers, by Warrant, or writing, Shall Lett, demise, or Grant, to any Tennant, to build or Set up, any Hearth, or Hearths, House, or Houses to wash or blow their Lead in, the Tenant So having Licence, may lawfully give, Sell, or Assign y^e^ Same during all Such Term, as he hath of and in the Same, paying the Lord's duty, and keeping the reparacons according to y^e^ Custome of the Occupation.

17. *Burning of thieves and Fellons from the Occupacō.*—ITEM according to y^e^ Old and Ancient Custome, if any Workman whatsoever he be, pick, or Steal, Oare, or Lead, Wood, Timber, Instrument, Utensil or tool incident to the Said occupacō or appertaining to any workman, & under y^e^ value of Twelvepence, then every Such Offender Shall forfeit unto y^e^ Lord for Such Offence Six Shillings and Eightponce to be levyed of his Goods without any Assurance. And if it be above y^e^ value of thirteenpence halfpenny and So presented by y^e^ Oaths of twelve men, then the Offender Shall be deemed taken, and reputed as a Thief or Fellon, and Shall be lawfull for the aforesaid Bailiffe and Lead Reeves, and to every of them, to Seize upon all the Offender's working house & houses, hearth & hearths, Lead, Oare, and all other Stuffe, & works whatsoever it be, being within y^e^ Precinct, and Limits of the Said disaforasted Ground of Mendipp, and thereof to answer y^e^ Lord y^e^ Issues, and proffits of Such goods so forfeited, and Shall take the Offender, and bring him where his house, or Oare is, his Instruments, Utensills, or working tools. to his Occupacō belonging, and then to put him into his house, or working

place and there Set Fire about him, and burn his working Tools about him, and so from thenceforth be banished from y^e^ Occupation for ever, before y^e^ Face of all y^e^ Miners there, and if ever he offend after, to be Committed to y^e^ Law of y^e^ Realm.

18. *Burying of ye dead bodies.—To make Ordinances.*—ITEM if any man by this dangerous and doubtfull occupation, do take his death, and be Slain by falling of the Earth upon him, by drowning, by Stifling with Fire, or otherwise, (as in times past many have been so murdered) the Workmen of that Occupation Shall fetch up that dead body, at their proper Costs, and charges, (although he lye threescore Fathome under y^e^ Earth) and Shall bury him in Christian burial. Provided always that all Such Ordinances as from time to time, hereafter Shall be ordained, established and made, by order of the Said Minery Court, for the further & better Order of the Said Occupation, be put in Use, that then all such Ordinances So made to Stand and remain for good and effectual Customs, available to be observed for ever.

ORDINANCES made, and agreed upon, at divers Minerye Courts, with y^e^ Lord's Consent, as followeth:—

CHEWTON: AT THE MINERIE COURT holden there y^e^ thirteenth day of Octob^r^ * in the Fifteenth Year of the Reign of our Sovereign Lady, Queen Elizabeth it is ordained as followeth.

19. *An Order for pitching and finding y^e^ Chine.*—IT IS ordered and agreed by the Jury and workmen p^r^sent and also Ratifyed by this Court, that if one man do lawfully pitch and find a Chine within his Ground, that is going down between two Stones he may lawfully follow his work in y^e^ Chine although he go a hundred Foot aside. And if another do pitch lawfully by the first pitcher, and do fall upon a Stone, being the back Side of y^e^ Chine of the first pitcher, and do find none Issue, then y^e^ Second Pitcher shall not burn, nor break y^e^ Stone untill he doth find Issue, and when he hath found an Issue, then may the Second Pitcher at that Issue, burn, and break the Stone by him found, and Sink down, and if he do come down upon y^e^ first Pitcher, then Shall y^e^ first Pitcher leave, & give place to y^e^ Second Pitcher, and hold himself to his first Ground.

20. *For buddlers in Widmore.—Void.*—ITEM at the Minery Court there holden the fourteenth day of March,† in the One and Twentieth Year of the Reign of our Said Sovereign Lady Queen Elizabeth, the Jury do agree, and Order that no man Shall buddle in a place called Widmore upon Mendipp aforesaid, from y^e^ feast of y^e^ Annunciacõ of our Lady, untill the Feast of S^t^ Michael y^e^ Arch Angell Yearly (for that many Cattel are hurt, & killed) upon pain of every man So offending, to lose twenty Shillings to y^e^ Lord of the Mannour of Chewton aforesaid.

ORDINANCES made and agreed upon between y^e^ Officers of Chewton aforesaid, and the Jurys Chosen, y^e^ third day of Aprill,‡ in the three and twentieth Year of the Reign of our Sov^r^gne Lady Queen Elizabeth, to be observed by the workmen, of the Hill within the said Mannor of Chewton, as followeth, by Thomas Luellen & his Fellows:—

* 1573. † 1579. ‡ 1581.

21. *To prosecute within 3 weeks, or else to be void.*—FIRST it is ordered and agreed by y^e^ Consent of y^e^ Court that if any man Shall Arest any Groove, Oare, or Lead, or any other mineral Stuffe, upon y^e^ tryal of any Controversy; he who doth arest the Same, Shall within three weeks after Such arest made, procure a Warrant from y^e^ Steward to y^e^ Store Bailiffe & Lead Rieves, for the calling of a Jury to try y^e^ Same (if the Steward or his Deputy be at home) otherwise y^e^ Store Bailiffe & Lead reeves, Shall Summon a Jury of themselves, or one of them for y^e^ Triall of the matter, and shall cause y^e^ Same Jury to yield up their p^r^sentment, or Verdict unto y^e^ Steward, or his Deputie, if he who have arested y^e^ same do not procure a Jury (as before is Said) shall be utterly void of his Claim and y^e^ Arest to be void also: so as y^e^ Officers do their duties, and charge a Jury according to the true meaning of this Order, they and either of them neglecting their duty Shall forfeit for every time twenty Shillings.

22. *He yt is found guilty to pay 6^s^. 8^d^.*—ITEM it is agreed that he or they who shall be found guilty by y^e^ Said Jury, of the matter that they Shall be charged withall, Shall pay to the Said Officer Six Shillings & eight pence, that is to Say Six Shillings to y^e^ Jury for their pains, and eight pence to y^e^ Said Officer. And if the partie or parties So found guilty refuse to pay y^e^ Same, the Said Officers Shall arest all y^e^ works, Oar, and Lead, as he hath w^th^in the precinct of y^e^ Same libertie for payment thereof.

23. *Entering & carrying by force.*—ITEM it is ordered and agreed that if any man, shall by any violent force, enter into any Groof, or carry away any Oare from any Groove, or by any violent means Shall take and carry away any Lead; although he do pretend Title to y^e^ Same (before it be given him by a Jury) he or they So offending, Shall forfeit and lose all Such works, Oare, and Lead, as he hath upon Mendipp aforesaid.

24. *Breach of arest.*—ITEM it is ordered and agreed that if any workman do break any arest of any Groove, oare, or Lead, (lawfully made by any of the Lead rieves, or one of them, and contrary to y^e^ Same arest) Shall carry away y^e^ Same Oare, or Lead, So that the Said Lead rieves or one of y^m^ do give lawful warning, before sufficient witnesse unto y^e^ party Defendant, that then he, or they So offending, Shall forfeit to y^e^ Lord all Such works, Oare, and Lead as he hath upon Mindip aforesaid.

25. *To Strike and draw bloud, to lose 5li.*—ITEM it is further ordered that if any workman shall violently strike another with his weapon, and draw blood, within y^e^ libertie of the works, Shall forfeit unto y^e^ Lord for every Such Offence a hundred Shillings of lawfull money of England to be levyed of his Mineral Goods within y^e^ Said Libertie.

26. *To arest before 5 fathom deep, or else to be void.*—ITEM it is also agreed that if any workman Shall know of any Groove to be wrought, and hath any Claim thereunto, or to any part thereof, and shall not arest y^e^ Same, before it be five Fathome deep and that then he, or they, So claiming or challenging, the Same to be void.

27. *Entring of bargains.*—ITEM it is Ordered, and agreed, that if any man Shall pitch a Grib, and Shall give or Sell any part thereof, or if there Shall

be any Contract, bargain, Scorsing, or buying, between partie and partie, he, or they which Shall So give, bargain, Sell, exchange, or grant, the Same, Shall forthwith enter the Same into y^e^ Officer's Book, with the day and Year of the Same bargain, and the Said Officer to take a penny for entering and not above.

28. *Giving Oare in pieces and Lead unweighed.*—ITEM it is ordered and agreed that no man Shall give any Oare, by Corfe full or pieces of Oare, from any main heap or after it be parted in y^e^ heaps, or any Lead, before it be weighed, and marked with y^e^ Minery mark, under pain of Six Shillings and Eight pence.

29. *To Sell more than he can justifie.*—ITEM it is Ordered that if any workman, Shall give, Sell, or exchange, any parts of any Gribs or Groves, and Shall not be able to justifie y^e^ Same Gift, bargain, or Sale, being entered into y^e^ Officer's book according to y^e^ Order aforesaid, and doth y^e^ Same willingly to deceive any man thereby, he or they So offending Shall be banished the Occupation.

30. *Putting out of parts before 5 Fathom deep.*—ITEM it is ordered and agreed that if any workman Shall after the first day of May next, put out any part, or parts of any Grove, to another to halfs, or to any Share, before it be five Fathom deep, and So brought down by him, or them that are partners in y^e^ Same, or at their Costs and Charges, without any Craft, collusion, or deceit (but only according to the true meaning of this Order) Shall forfeit to the Lord, all Such parts, as he Shall So put out, or he Shall find one Corfe full of Oare in y^e^ Same.

31. *For buddling in y^e^ Minerie.*—ITEM it is ordered and agreed that none shall buddle in the Minerie from the third day of March, untill Michaelmas Yearly except it be so convenient a place as the Officers think good, and the partie who shall be Suffered to work, shall be known well to be an honest man, and to put in Sureties to the Said Officers (for y^e^ time being) for his good behaviour, upon pain of forfeiture of all Such Stuffe as he, or they Shall work upon.

32. *For entering grooves privily to know the Secrets.*—ITEM it is ordered and agreed, that if any workman Shall by Night or by day privily enter into any groove, without y^e^ Consent of any of y^e^ Partners of any Groove to y^e^ Intent to know y^e^ Secrets of the Same Grove, or to take away any Tools, ropes, Candles, or any other Instrument belonging to y^e^ Same, he or they So doing Shall be banished from the Occupation.

CHEWTON: AT THE MINERY COURT holden y^e^ Sixteenth day of October,* in the Three and Twentieth Year of the Reign of our Sov^r^gne Lady Queen Elizabeth, it is ordained and Established as followeth.

33. *For burned & banished Men.*—FIRST the Jury do order and agree, that every person and all persons (being burned and banished from the Hill, and Occupation) Shall be utterly and clearly discharged, from working or having

* 1581.

any thing to do within this Libertie, and all Such works, Oare, and goods as they and every of them have, Shall be Seized, to y^e^ Use of the Lord of the Mannor of Chewton presently.

34. *Approbrious or unseemly words.*—ITEM the Jury do order, that if any person shall abuse another with any approbrious words, or unseemly Termes, Shall forfeit for every Such Offence, Twenty Shillings, whereof to the Lord of the Liberty, Ten Shillings, and to the partie abused, the other Ten Shillings, and that y^e^ Lead Reeves or Store Bailiffe, upon Such Complaint, & proof made Shall arest, and Stay all Such works, Oar, and Goods, as y^e^ partie Soffending, hath within y^e^ Same Liberty.

CHEWTON: AT THE MINERY COURT there holden, the Fifteenth day of October,* in the Four and Twentieth year of the Reign of our Sovereign Lady Queen Elizabeth, it is ordained and established as followeth.

35. *Carrying of Lead, or Oare unweighed, or unmarked.*—FIRST it is ordered and agreed, by y^e^ Jury aforesaid, and also by Consent of y^e^ Court, that whosoever from henceforth, Shall carry away Lead, or Oare, from the Mineries aforesaid, unweighed or unmarked, Shall forfeit all his goods, and be banished from the Hill.

CHEWTON: AT THE COURT there holden y^e^ Thirteenth day of October† in the Five and Twentieth Year of Our Said Sov^r^gne Lady Elizabeth it is ordained as followeth, made by Thomas Burge, and his fellows.

36. *No Weapons but working Tools.*—FIRST that no workman of this Minerie, shall bear, or carry amongst the Works, any Weapons, other than Such Tools as are fit for y^e^ Occupation, upon pain of Fourty Shillings, to be Levyed of his or their goods by way of distress, without any Assurance.

37. *No taking under Colour of Title.*—ITEM that no man under y^e^ Colour or pretence of Titles (after arests is Made) may take or Carry away any man's Goods, Oare, or Lead, or other thing belonging to the Occupation, untill the Title be tried, or after any Verdict is given, upon pain of Forfeiture of all his and their Goods, and be banished y^e^ Occupation.

38. *Resisting y^e^ Lords Officers.*—ITEM it is further Ordered, that if any person or persons, at any time hereafter, Shall make any Resistance, or Assault upon any of y^e^ Lord's Officers for the time being, in Serving of any Amersement, or any other duties, due upon any p^r^sentment, made by the Twelve men for y^e^ time being, Then every Such person, and persons, So Forfeiting to be bannished y^e^ Occupation for ever.

39. *Entering into Grooves after Verdict is given.*—ITEM that if any person, or persons, shall Enter in to any Grove, or Oare, or mineral Stuffe, upon y^e^ Possession of any person or persons, which is or Shall be at any time given by Verdict, by due Course of y^e^ Law of y^e^ Occupation, to lose all his Goods, and be bannished the Occupation.

* 1582. † 1583.

40. *Officers to pay for neglect, of their Office.*—ITEM it is ordered and agreed by y^e^ Said Jury, that every Order and agreement made, by Authority of the Minerie Court, Shall be by the Officers, duely executed in all points, according to y^e^ true meaning of the Said Orders, and if any man shall make default therein, and the Said Officers be found negligent in executing y^e^ Same, they and ev^r^y of them Shall Forfeit for every time that they Shall be found guilty fourty Shillings, the One half to y^e^ Lord, and y^e^ other half to him that knoweth, and justly accuseth y^e^ Said Officer.

CHEWTON: AT THE COURT OF THE Minerie there holden the last day of Aprill* in the Six and Twentieth Year, of the Reign of our Sov^r^gne Lady Elizabeth, Queen of England, it is ordained as followeth, by Thomas Cole, M^r^ Thomas Hippisley, and their Fellows.

41. *Goods arrested Shall not be removed.*—WE DO ORDER and agree, if any arests, shall be made hereafter, lawfully by the Lead Reeves, or one of them, according to the Orders in that behalf, that the Goods So arrested, Shall remain under arrests, without Sureties to be taken, untill Such time as the matters shall be determin'd, either by Verdict, or Composition of the Parties, between whom y^e^ Controversie is, or Shall be, or otherwise Licensed by a Jury of Twelve men, under pain of Twelve pounds for every default of y^e^ Lead Reeves offending in y^e^ p^r^mises. Provided that if any Groove shall be arrested, the Groofe to be wrought lawfully by Licence, if need do require, but y^e^ Oare to lie Still, at y^e^ Grooves' Mouth, untill y^e^ Title be Tried under y^e^ like pain.

CHEWTON: AT THE MINERIE COURT there holden, the Thirteenth day of October,† in the Said Six and Twentieth Year of the Reign, of our Said Sov^r^gne Lady Queen Elizabeth, it is Ordained as followeth, by William Cole Jun^r^. and his Fellows.

42. *An Order for y^e^ Summoning or warning of the Minery Jury.*—WE DO ORDER that from henceforth y^e^ Lead Reeves Shall Summon a Jury of Four and Twenty of the most Substantial workmen of y^e^ Occupation, within the Minerie, or w^th^in y^e^ Groving Pitts, as well as of the Lords Tenants, and if y^e^ Same Persons, being So Summoned, by y^e^ Lead Reeves, or one of y^m^ whatsoever he be do make default, and do not appear, at the day and place So lawfully assigned and warned by y^e^ Officer afores^d^ that then the Parties being so sum̃oned, Shall Forfeit Twenty Shillings a man for his default, and if the Lead Reeves do not their duties in Summoning the Jury, at the two usual Minerie Courts Yearly, that then they shall pay Twenty Shillings a man, for their defaults, and the Same amersement to be levyed of y^e^ first Goods of any Such Offender, as Shall be found, within the Lord's Manor of Chewton.

CHEWTON: AT THE MINERY COURT there holden the Fourteenth day or Aprill‡ in the Eight and Twentieth Year of her Said Majestie's Reign it is Ordered as followeth, by John Adams and his Fellows.

43. *An Order for levying of Amercements or pains forfeited.*—WHEREAS great disorders and Enormities, and Offences are daily committed and done within the precint of the Minerie of Chewton, for want of due Execu-

* 1584. † 1584. ‡ 1586.

tion of Such Orders as are alreadie Established, for the good Government of the Said Minerie, to the great hurt, hinderance, and prejudice, as well of the Lord of this Minery, as also of the workmen of the Same, for that the Lead Reeves, and Store Bailiffes of the Said Minerie, cannot levie y^e^ Amersements, and Pains Forfeited for breach of Orders; partly because the great Offenders and Trespassers, either do convey away, their goods out of the Libertie, whereby the Officers of this Court, cannot Levy any goods of theirs, within the Minerie, partly for that by Force they do withstand the Officer, when they come to levy any amercement, or pains forfeited, partly for that by other fraudulent conveyances, they do alter the propertie of their Goods. for Reformation of all which Premises, and due execution of Justice, we of this Jury do Order and Decree, that whatsoever Person, that is or Shall be a Workman, within the Said Libertie and Minerie of Chewton, Shall from henceforth refuse to pay unto y^e^ Said Lead Reeves, or Store Bailiffe, or to either of them, for the time being, any Amersement, or Pain forfeited, extracted out by the Steward, by reason of any p^r^sentment made by the Jury, at any Minerie Court, and Shall withold the same Amercement, or pains forfeited from the Said Officers, or any of them demanding y^e^ Same to y^e^ Use of the Said Lord of the Said Manor of Chewton for the time being, or to any workman to whom by vertue of the Said p^r^sentment it shall be due, untill y^e^ next Minerie Court, if at y^e^ Said next Minery Court the Said Offender doth not pay, or Satisfie the Same amersement or pains forfeited, in open Court, or else Compound w^th^ y^e^ Lord's Chief Officer, for the time being for y^e^ Same, and w^th^ the party to whom part of this Same amercement is due, that from thenceforth he shall be bannished y^e^ Occupation, and be excluded from being a workman, within the Said Libertie & Min^r^ye for ever.

44. *Default between Court and Court.*—We do also Order that whatsoever workman he be, that Shall be lawfully warned, by the Lead Reeves, or one of them, to appear and Serve in any Jury between y^e^ Minery Courts, and hath no lawfull Cause to y^e^ Contrary, that for default of Such Service, Shall be amerced every Man Ten Shillings.

CHEWTON: AT THE MINERY COURT there holden y^e^ Nineteenth day of October* in the Nine and Twentieth Year of the Reign of our Said Sov^r^gne Lady Queen Elizabeth, it is Ordained as followeth by Thomas Plumley and his Fellows.

45. *For those y^t^ intermeddle w^th^ burned, or banished men.*—It is Ordered and Agreed at this Court, that whosoever at any time hereafter Shall retain in his Service, any burned, or banished man, from this Occupation, for Fellony, or shall be Copartner, or work for wages with any Sush burned, or banished, man, or Shall buy, Sell, or Exchange, or any way intermeddle with any Such person, for any Minerall Causes, after proclamacō made, and notice given to y^e^ Workmen, that the Same person, is burned or banished, Shall lose all his Goods, and be bañshed y^e^ Occupacō himself.

46. *For levying of Executions given by Verdict of a Jury.*—Item we do order, and p^r^sent, that if any partie, or parties do make recovery of any Goods, by Verdict of a Jury, and thereupon have warrant of Execution, from y^e^ Steward of y^e^ Court, to y^e^ Lead Reeve's or one of them, to levy the Said Execution,

* 1587.

upon the Goods of y^e^ Defendant, under Arest, the Said Lead Reeves, or one of them, to whom Such Verdict of Execution Shall come, Shall forthwith Levy y^e^ Said Execution, to the true meaning and Effect of y^e^ Verdict, under the pain of Fourty Shillings making default, the One half to the Lord and the Other half to the partie grieved.

CHEWTON: AT THE MINERY COURT there holden the Five and Twentieth day of Aprill,* in y^e^ Three and Thirtieth Year, of her Said Majestie's Reign, it is Ordained as followeth.

47. *Failes for Lott Lead.*—It is found by Ancient Custome of Mendip that every Workman ought to receive of the Lead Reeves, or one of them, one Faile to be Cut out of y^e^ Store of y^e^ Lott Lead, which they & every of them do weigh, the Stock to remain with y^e^ Lead Reeves, and the Faile with y^e^ Workmen So Lotting, untill the Next Court, which Usage of late, hath been omitted, and not Used, whereby the Lord of this Man^r^ is greatly annoyed, hurt and prejudiced, for that the Lead Reeves cannot justly be Charged, with Lott So laid out to them by the Workmen, We do therefore agree, and p^r^sent, that the aforesaid Usage shall be newly put in execution, and that every person and persons having Occasion to weigh Lead, and Lott for the Same, Shall Account with y^e^ Lead Reeves for the time being, for their Lead weighed, and Shall receive of the Lead Reeves one faile of the Number of Lead So weighed by him, or them before, he or they departeth, and also shall bring y^e^ Same faile to y^e^ Minerie Court next to be holden, at Chewton, and make delivery thereof in open Court. under pain of every man making default herein, twenty pence, to be paid to the Lord of this Mannour, of Chewton aforesaid for y^e^ time being.

CHEWTON: AT THE MINERY COURT there holden the Eight and Thirtieth Year of her Said Majestie's Reign, and y^e^ Seaventeenth day of October,† it is ordained as followeth, by William Cole, Thomas Tagge and their Fellows.

48. *No man shall weigh Lead but in y^e^ p^r^sence of an Officer.*—Whereas we of the Jury be informed, by the Officers of this Court, that divers persons do carry Out Oare raised within this Liberty, into Forreign Mineries, to Smelting and converting into Lead, and do weigh the Same, without the presence of One of y^e^ Lord's Offic^rs^ appointed for that Service. We of the Jury with y^e^ Consent of the Court, do order, and p^r^sent that if any man do carry or cause to be carryed, any Oare digged, or raised within this Mannor of Chewton, to any of y^e^ aforesaid out Mineries to washing, or converting into Lead, he or they shall not weigh, nor cause to be weighed, any Oare, or Lead, except one of y^e^ Officers of Chewton be present, provided always that at Hartrie Minerie one of them do give their attendance, upon the weighing days from Eight of y^e^ Clock untill Ten, of the Same day, and in all other Mineries, every weigh day, from Ten untill Three in y^e^ After Noon, and take Notice of all Such Lott Lead, & Oare, as Shall be then and there due, and if any man shall break this Order, he, or they Shall lose for their first Offence Fourtie Shillings, and for their Second Offence to loose all his Goods and for y^e^ third Offence, to be banished the Occupation of this Hill or Libertie of Chewton for Ever.

* 1591. † 1596.

49. *No man shall carry Oare before it be parted.*—ITEM we do Order, and agree with y^e^ Consent of this Court, that from, and after this Our presentment Shall be published, what manner of person, or Persons, as Master, partner, or hired Man, Shall Land, or Cause to be Landed, or consent to y^e^ Landing of any Oare, out of any Groof, by the day time, or by y^e^ Night Season, and the Same Oare Shall not be lawfully parted, divided, and Lotted, according to y^e^ true meaning of y^e^ Ancient Custome of y^e^ Occupacō whosoever Shall be found to carry any Oare y^t^ Shall not be divided, (as is abovesaid) Shall be taken as Fellons, and burned out of the Occupation, according as is Set down, in the above and ancient Custome.

50. *For buying of Oare on Sundays and holy days.*—ITEM we do Order and agree that if any person whatsoever, do buy or Sell at Mendipp, any Oare upon Sunday, or holy day, y^e^ parties So offending, Shall forfeit for every Such Offence to y^e^ Lord of y^e^ Said Mannor, fourty Shillings to be levyed of any of his Goods without any further Assurance.

CHEWTON: AT THE MINERIE COURT there holden the Seaven and Twentieth day of Aprill* in the Fourtieth Year of her Said Majestie's Reign, it is Ordained by John Tucker, and his Fellows.

51. *Unlawfull Groves, or holes.*—WE DO ORDER and agree, that what Groovcs or holes Shall be found, to lie unlawfull, or uncovered, within this Mannor of Chewton, after Trinity Sunday Next, whereby any man's Cattell may fall in, to y^e^ Loss of the Owner of y^e^ Said Cattell, all Such Workmen, & partners of the unlawfull Grooves and holes aforesaid, Shall forfeit, and lose, for their Offences in that behalf, Twentie Shillings, to be levyed by the Store Bailiffe, or Lead Reeves, or any of them, of any Groves, Lead, or Oare the One half to y^e^ Poor of Chewton, and y^e^ Other to those y^t^ find out Such fault, and make proof thereof against any Such as Shall offend, the proof to be made by any two of y^e^ Tenants of Chewton, or by any of y^e^ Lead Reeves.

CHEWTON: AT THE MINERIE COURT there holden the third day of Aprill,† in the Two and fourtieth Year of her Said Majestie's Reign, it is Ordained by John Hoskins and his Fellows.

52. *For them that break, or Steal draught Stillions.*—ITEM We do Order that if any person or persons shall be justly proved, to break, Steal, or carry away, any draught Stillions out of any man's Gribb, Grove, or Ground, that they and every of them Shall for y^e^ first Offence forfeit to y^e^ Lord of the Mannor, the Sum of Ten Shillings, and for y^e^ Second Offence in the Same Case to be bannished from y^e^ Occupation.

CHEWTON: AT THE MINERIE COURT holden the Twentieth day of October,‡ in the first Year of the Reign of our Sov^r^gne Lord King James &c. it is ordained as followeth by John Adams, and his Fellows.

53. *An Order for Hacks throw.*—WHEREAS the Workmen of the Hill within this Mann^r^ of Chewton, formerly have had but twice Eighteen Foot, from

* 1598. † 1600. ‡ 1603.

their first pitch to labour in, according to an Old Order in that behalf made, the ground being Short, the Charge of Workmanship Great and y^e^ chiefest places tried, and for that y^e^ Workmen of y^e^ Occupacō Shall with better will bestow Charges, within this Manno^r^ of Chewton it is Ordered and agreed by y^e^ Jury with full Consent of y^e^ Court, y^t^ every Workman, which from henceforth Shall have any Grove, Gribb, Pitch, or Marke within this Libertie, Shall have Eighteen foot of Ground, on every side of his Pitch, as he is, or Shall be the Elder Pither, to find his Chine or Chines, and having found a Chine, or Chines, within y^e^ Said Eighteen Foot, then to have his Said Hacks throw, after his Said Chine, and Chines every way, and it Shall be lawfull for him to have, hold and enjoy y^e^ Said ground, in length, & breadth accordingly, how many Courses, or Chines Soever he findeth, w^th^in y^e^ Plumb of y^e^ aforesaid Ground, So as he findeth y^e^ Said Chines, or Courses within y^e^ Eighteenth foot of his first Pitch.

CHEWTON: AT THE MINERIE COURT there holden the Sixth day of October,* in the first Year, of our Said Sov^r^gne Lord King James, it is Ordained as followeth, by William Butcher and his Fellows.

54. *An Order for payment of wages and Charges.*—IT IS ORDERED and agreed at this Court, with the Consent of y^e^ Court, the Jury and workmen p^r^sent, that if any mann^r^ of person within this Liberty Shall be behind, in payment of wages, or Charges, for any part or parts, in any Grove, or Groves, or any other Mineral Goods whatsoever, the wages being duely earned, and lawfully demanded, of y^e^ party, or partys, whatsoever So owing, that then it Shall be lawful for any workman So grieved to go to y^e^ Steward of y^e^ Said Manour for y^e^ time being, or his Deputie, and there to make Oath for Such wages, or Charges as Shall be or is unpaid, & upon Such Oath So taken, the Lead Reeves or one of them, Shall make proclamation at y^e^ Grove, or place where y^e^ wages and Charges was So carned, or due to be paid, and if y^e^ party, or partys, defendant, do not Satisfy and pay y^e^ Same wages and Charges, within Fourteen days, next after proclamation So made, that then y^e^ partye, or parties So grieved, Shall have and enjoy y^e^ Same part, or parts, or any other Minerall Goods whatsoever, where y^e^ Same wages and Charges was So earned, and due to be paid, notwithstanding any other Order heretofore made, concerning the payment of wages.

CHEWTON: AT THE MINERIE COURT there holden the Twelfth day of July† in y^e^ Seaventh Year of his Said Majestie's Reign &c.

55. *An Order for Odd Grounds and Catches.*—WE of the Jury do Order and agree, that from henceforth after y^e^ Five and Twentieth day of December, next ensuing, no man Shall pitch, or work between any Pitches, or Groves under y^e^ Colour of an Odd Ground, by workmanship to come into another man's Chine, or Course within his or their hack's throw, but he, or they Shall lose all his, or their Labour, and Charges, and be void of all Claim, or Challenge, as they do, or Shall pretend to y^t^ place, and no Oare of any Such place being Landed, to be carryed, untill it be proved out of any Elder Pitcher's Ground, upon pain of losing his and their Goods, and be bannished their Occupation.

* 1604? † 1609.

56. *For Pawns.*—We do Order, and agree that whosoever he be, that is a workman, or other dealer, upon y^e^ Hill and Libertie of Chewton, that hereafter Shall pawne, pledge, or make Over, any parts of Oare, Groves, Lead, Brocks, Staggs, Small Stuffe, or any Minerall Causes Shall Enter y^e^ Same into y^e^ Store Bailiffe's Book, for y^e^ time being or else y^e^ Said Pawn to be void, and that y^e^ Said Store Bailiffe Shall take for his pains, but two pence, that is a penny each Pawner and taker of y^e^ Pawn, or else the Pawne and Pledge to be Void.

CHEWTON: AT THE MINERIE COURT holden the last day of September,* in the Sixth Year of the Reign of King James &c. by John Bernard and his Fellows.

57. *Seaven Foot.—Made Void.*—We do Order and agree that from and after the Five and Twentieth day of July next coming, it Shall be lawfull for any Workman, to Enter by the Gift of an Officer into any Pitch or Grove within y^e^ Libertie, that is not Seaven foot deep bent with Three Course of Timber, and a pair of draught Stillions upon y^e^ Same.

CHEWTON: AT THE MINERIE COURT holden the Sixth day of October,† in the Eleventh Year of King James, by John Adams, and his Fellows.

58. *The Law Hack detained.—Throwing the Hack in due time.—Who ought to throw y^e^ Hack.*—Whereas Richard Durham one of y^e^ Lead Reeves about the time that Troubles were at Stoke Hill, had our Law Hack in his Custody, and hath negligently, or wilfully departed therewith, and whereas we find by Our Evidence, that M^r^ John Gilbert, and Walter Kingfitt, have had y^e^ Same Law Hack, of Our Libertie of Chewton in their keeping, Since y^e^ Said Richard Durham hath departed from the Same; We do hereby Order, and p^r^sent, y^t^ the Said John Gilbert or Walter Kingfitt, or any other Workman of our Said Occupation, that Shall after the publication of this Our p^r^sentment, unjustly, unlawfully or wittingly, have, keep, detain, imbessel, Shift away, depart with, or make away the Said Law Hack, and Shall not deliver y^e^ Same unto Richard Savidge one of our Lead Reeves of Chewton, within Fourteen days next after the Publishing of this our p^r^sentment, or Shall at any time after y^e^ publishing of this our p^r^sentment, presume to throwe the Same Law Hack, out of any Grib, or Grove, that is or Shall be brought unto Oare, within our Libertie of Chewton, and shall not receive y^e^ Same Law Hack of one of the Lead Reeves, as he Shall Stand Orderly in the Same Grib, or Grove to y^e^ Waste, or Girdle Stead, orderly to throw y^e^ Same, according to our Ancient Custome, or Shall throw the Same Hack, at any Undue time, whereby any Workman Shall be unjustly prejudiced, or Shall not by just Right and Title be either y^e^ Pitcher, or One of y^e^ Elder Partners, of the Same Grib, or Grove, according to our Ancient Custome, that then he, or they or any of them, that Shall So offend, or break any point of this our Order, Shall be banished from y^e^ Said Occupation for ever.

59. *An Order to restrain forreign Suits.*—Whereas by our Ancient Custome of our Minerie Court of Chewton, appearing unto us, as well by divers

* 1608? † 1613.

ancient Men's depositions, taken many Years Since, as also by divers Records, p^r^sentments, and Orders by us Seen, and perused, Some in the time of the Late King, of famous memory, Henry y^e^ Eighth, Some in the time of the late Queen Mary, and Since, that no workman, of y^e^ Occupation of the Miners of Mendip, Should Sue, arest, or trouble any other workman, of y^e^ Said Occupation, for, touching or concerning, any Minerall Cause or Controversie, arising or growing within y^e^ Liberty of the Minery Court of Chewton, without License obtained, according to an Order in that behalf, except it were upon Specialtie in writing for meer debt; & because there is not as Yet Sufficient pains and punishment, inflicted upon the breaker of that Good and necessary Law, Custome, and Order in that behalf, divers honest poor Workmen, that Serve in Minerie Juries there, who spend much time and travail, without any benefit, at all to hear, end and determine Controversies arising among the Said Workmen, according to the Said Custome and Orders, and according to Right and equity of late days, have Usually been by some Malicious and turbulent persons, if they cannot have their Causes determined, according to their own likings, although it be against Order, Equity, and all Right, verry greatly threatned, Sued, Molested and troubled, in the King his most Excellent Majestie's High Court at Westminster, and also before y^e^ late Rev^r^nd Judges of Assizes of y^e^ Countie of Somersett, by Reference and Petitions, who lately gave their Learned Opinions, that Minerall Causes were best known, to Minerall men, and fittest to be determined by Mineral Juries, according to whose Learned opinions, agreeing with our said Ancient Custome, Record, p^r^sentment and Orders of our Said Minerie Court, for the good of y^e^ Said Workmen of the Occupation, for the avoiding of those long and tedious Suits in the Said High Courts for the more Speedy triall, and due Execution of Justice in convenient time of our Said Minerie Court, to be had, & executed. We of this Minery Jury being enabled, as well by our Ancient Custom comprehended within the Law of Reason, as also by ancient depositions of the Workmen of the Occupation, by Record & p^r^sentment of Our Said Minerie Court, namely by an Order Made in the Second year of the Late Queen Mary, between the then Lord of Chewton, and the men of the Said Occupation, and entered in y^e^ Book of Record of the Said Min^r^y Court, do with y^e^ Consent of the now Lords Officers of the Said Minery Court and with the good liking of discreet men of y^e^ Said Occupation, do Order, that no workman, nor workmen of the Said Occupation, Shall from & after y^e^ publishing of this our Order, Serve with Subpœna, or any other process, or Sue, arest, or trouble, or Shall cause and procure, or animate any other Workman, or any other person, or persons, to Serve w^th^ Subpœna or other process, or to arest Sue, or trouble any Workman, of the Said Occupation, for any Mineral Cause, or Controversie alreadie grown, commenced, or done, or that Shall hereafter grow, arise or happen, within the Said Libertie of the Said Minerie Court of Chewton, but only in the Said Minerie Court of Chewton, if it may or ought by Custome or Orders of y^e^ Same Court, be there lawfully decided, adjudged or determined, without any Offence, or Contempt to y^e^ King's Majesties prerogative Royall, or any of his hon^r^ble High Courts at Westminster, neither Shall Serve with any Subpœna, or other process, or otherwise Sue, arest, or trouble, or Cause procure or animate any Mineralman of y^e^ Said Occupation, or any other person or persons, to Serve with Subpœna, or other process, or to Sue, arest or trouble any Mineralman of the Said Occupation, for any Cause, Controversie, thing or matter whatsoever alreadie grown, or done, or which hereafter shall happen,

to arise grow, or come for, concerning, or by reason or means of any Mineral Cause aforesaid, but only in the Said Minerie Court of Chewton, if by the Laudible Custome, and Order of y^e^ Same Court, it may or ought lawfully to be tried, desided, or adjudged there without any Offence or Contempt to the King's Majestie, his Prerogative Royal, or any of his Hon^r^ble High Courts at Westminster, except he or they Shall be thereunto Licenced, according to an Order in our Said Minerie Court in that behalf, or unlesse that shall be upon Bands, Bills, or other Specialtie, for meer debt, or unless it Shall be upon Some Subpœna, or other Processe that is alreadie Served upon any workman of the Said Occupation before y^e^ publishing of this our Order, or unless, it Shall be upon Some Suit that is alreadie commenced, before y^e^ publishing of this Our Order, in any of the King's Majestie's hon^r^ble High Courts at Westminster, by Bill or any other Information, alreadie exhibited, or by Some Petition, Complaint, or Reference that is now depending, before any of the Honourable Lords of the King's Majesties honourable privy Council, or before the Said Reverend, and Learned Judges of Assizes, or any of them before any Arbitrators, Commiss^r^s or Committees, or by their or any of their directions alreadie Assigned, or for any Riott, Rout, breach of the Peace, or Some Such like Contempt, or Misdemeanor, upon pain of Losse and forfeiture of all his and their minerall Goods, within this Libertie of Chewton, the One half to y^e^ Lord, of this Libertie, y^e^ other half to the partie, or parties that Shall be ^so^ Sued with any Such Subpœna, or other processes, or that Shall be So Sued, arrested, or troubled, contrary to the purport, Effect, and true meaning of this Order, & upon pain of banishment from y^e^ Said Occupation for Ever, immediately after y^e^ Same Offence So committed or done, contrary to the purport, Effect, and true Meaning of this our Order, and this our Order to Stand in full force, and Effect for ever.

CHEWTON: AT THE MINERY COURT there holden the Nine and Twentieth day of March,* in the Thirteenth Year of our Said Sov^r^gne Lord King James, it is by Thomas Wilcox and his Fellows Ordained as followeth.

60. *An Order for those y^t^ find & Sell goods, & not to Sell before he make the Lead Reeve acquainted.*—FOR AS MUCH as great Complaint is made by divers workmen of the Occupation, for that Sometimes, the many heaps of Oare are rifled, and Sometimes heaps of Oare, after Lotts cast, are pulled abroad, and the best Oare taken away, without the knowledge or Consent of the Owners, to their great hurt & damage And whereas of late divers bargains of Oare being of Sev^ll^ Colours & qualities, (as if they had been taken, from Several Groves) have been sold; the Sellers thereof having no lawful title thereto, but pretending they did find the Same, and for that y^e^ Same hath been Sold at a lowe Rate, and underprice, we rather think it Stollen than found. for the avoiding thereof, and for y^e^ general good of the Occupation, WE with y^e^ Consent of the Court do order and agree, that whosoever Shall after the publication of this our p^r^sentment, offer to Sell, or Shall give, or exchange, or Shall consent to the Sale, gift or exchange, or any other conveying of any Minerall Goods whatsoever, as working Tools, Oare, Lead, or any other things incident to y^e^ Occupation, under colour of finding the Same, before he make one of the Lead Reeves acquainted therewith; except he or they make good Title thereunto in his or their own, or as lawfull Deputies

* 1615.

for Some other workman of y^e^ Said Occupation; he or they So offending if it be proved to be above y^e^ Value of Twelve pence, Shall lose all his and their Minerall Goods to y^e^ Lord of this Royaltie, & be bannished the Occupation, AND further whosoever Shall Offend in the like Offence as is aforesaid, under the Value of twelve pence, Shall forfeit to the Lord of this Royaltie twenty Shillings to be levyed out of y^e^ Mineral Goods of any such Offender.

CHEWTON: AT THE MINERALL COURT there holden, the Five and twentieth day of October* in the thirteenth Year of our Said Sov^r^gne Lord King James, it is Ordained by John Playster, and his fellows as followeth.

61. *An Order for the Minerie.*—WE DO ORDER and agree, by the Consent of y^e^ Court, that after this our p^r^sentment Shall be published, that whatsoever workman, or workmen do, or Shall work, within y^e^ Libertie of Chewton Minerie, at any great buddles, upon any Small Stuffe Shall upon warning of y^e^ Lords Officers, or one of them, bestowe two days work apiece every Year when it Shall be thought fitt by the heath men, or any of them to be done under pain of every one offending to forfeit five Shillings to be levyed of his or their Goods to the Lord of y^e^ Manour.

CHEWTON: AT THE MINERIE COURT there holden the last day of Aprill,† in the Fifteenth Year of y^e^ Reign of our Sov^r^gne Lord King James it is Ordained as followeth.

62. *An Order for laying of fires.—Void.*—FIRST by the Consent of y^e^ Court we do Order, that no workman, or workmen, within y^e^ Manour of Chewton, after the publication of this our Order, Shall lay in any Rake, Chine, or Course of Groves, any Fire in any Grove y^t^ the Smoak thereof may hurt or Offend any their Neighbour Groviars, but on y^e^ Saturday at after Noon, or y^e^ Holy day Eve's after Noon, upon pain of the Losse of Ten pounds, of lawfull money, the One half to y^e^ Lord of y^e^ Manour and the Other half to y^e^ partners of y^e^ Grove that is Offended, or hurt thereby, and that they kindle not their fire either of y^e^ days aforesaid, without giving of warning to their Neighbouring Groviars under y^e^ like pain.

CHEWTON: AT THE MINERY COURT there holden y^e^ Fifteenth day of October,‡ in the Fifteenth Year, of y^e^ Reign of our Sov^r^gne Lord King James &c. it is Ordained as followeth.

63. *For buddling in Rush Meare.—Void.*—WHEREAS great complaint is made unto us of y^e^ Jury by the Inhabitants of Chewton, for that there are certain buddles newly layd at a place called Rush Meare, and other places within Chewton aforesaid, and that the Tenants have, and are like to receive great losse thereby; WE do therefore by Consent of the Court, Order and agree, that if any person or persons Shall buddle at the Said Rush Meare, or at the Cleeves, or at any other new erected Place within this Libertie, after y^e^ publication of this our p^r^sentment, Shall forfeit for every day they Offend therein three Shillings fourpence, the One half to y^e^ Lord of this Libertie, & the other half to y^e^ Person that Shall approve this Offence against

* 1615. † 1617. ‡ 1617.

him. Also we do Order, and agree that all person, or Persons that Shall buddle in any Old Ancient place within this Libertie, Shall keep the Water in his Course into the Swallowitt as it hath Used heretofore to run, or else to lose twenty Shillings, the One half to y^e^ Lord, and the Other half to y^e^ person that Shall prove the Offence.

64. *For petit Jurys to give their Verdict in 14 days.*—ITEM we do Order and Agree that if any Petty Jury Shall be impannelled, and Sworn to trie any Controversie, between any parties and Shall receive Evidence for the matter wherewith they Shall be Charged, and do not yield up a Verdict in writing to y^e^ Steward, or his Deputie for y^e^ Same matter, within fourteen days next after they are impannelled, and Sworne, then they and every One of them that Shall be found faultie therein, by the Censure of y^e^ Next ensueing Grand Jury Shall be bannished y^e^ Occupation for ever.

CHEWTON: AT THE MINERIE COURT there holden y^e^ Eighteenth day of October,* in y^e^ Seaventeenth Year of the Reign of our Sov^r^gne Lord James by the Grace of God King of England France and Ireland Defender of y^e^ Faith &c. and of Scotland the Three and Fiftieth, &c. it is ordained as followeth by John Moore and his fellows.

65. *The Confirmacō of the books indented.*—FOR AS MUCH, as we of this Minery Grand Jury, whose names and marks are here Under written, have many Suits, Bills of Complaint, and grievances before us depending, preferred as well in the behalf of the Lord of this Libertie, against many Offenders; as also between workman and workmen, for differences between them committed, against the Laws & Customs of the Occupation, which hath caused many meetings of us the Said Jury, both to our great trouble and Charges, and perusing the Ancient Laws and Customes of the Said Occupation we find by Ancient depositions made, in the time of our Sov^r^gne Lord King Henry the Eighth of famous memory, and likewise perusing the Ancient Laws and Customs of y^e^ Said Occupation, y^t^ in the Second Year of our late Sov^r^gne Lady Queen Mary the Customes were then concluded between the then Lord, and workmen for y^e^ time being, by Indenture whereof the One part remaineth, with y^e^ Lord and his Heirs, and the Other with y^e^ Teñts of Chewton, to y^e^ Use of y^e^ Said Workmen, dated y^e^ tenth day of July in the Year aforesaid. And amongst divers other things, we find in the End of the Said Indenture, that power and Authority is given to any Minery Grand Jury, as they Shall See good Cause to make and Ordain Ordinances and Laws, for the better Government of y^e^ Said Occupation, as by y^e^ Said Indenture more at large appeareth; by Vertue whereof divers Minerie Grand Juries, at Sev^ll^ Courts have made many Ordinances in divers Years Since y^e^ Said Indenture; many of which Ordinances, in Some things uncertain, and Some things repugnant, one to the other, which of late hath bred great Offence to y^e^ Lord of the Manour, trouble to his Officers, and hurt to the workmen of y^e^ Occupation WE of this Jury Seeing the imperfections hereof, that thereby ariseth the inconvenience, and also understanding that the Indenture remaining with y^e^ Tenants of Chewton, to the Use of y^e^ Workmen of y^e^ Occupation is lost, and no man knoweth where it is, do with good advice and deliberation; and with care to reduce y^e^ Said Customes to more certain and better Forme, and with Consent of the Lord and

* 1619.

Workmen, Order and agree that from and after the publication of this Order, that no Order nor Ordinances whatsoever heretofore made, Shall Stand in any Force or Effect, but only Such Order & Ordinances, as are in two books p^r^sented by us of this Minery Grand Jury, which books are Indented, according to y^e^ Old Custome & the one of them to remain in the Custody of the Lord, & his Officers, and y^e^ other to be in the Custodie and keeping of the Foreman, of the Minerie Grand Jury; untill the next Minerie Court holden at Chewton, and there the Said Foreman for the time being to make delivery of the Said book in open Court to the Foreman of the next minerie Grand Jury there Sworn; and So every Foreman that Shall have y^e^ Keeping of this book, make delivery thereof accordingly, in open Court, to the next Foreman, So as the Said Foreman, have warning of the Said Court by the Lord's Officers, or their deputies; and So the Said book to be delivered from Foreman to Foreman for ever. And what Foreman of the Minerie Grand Jury Soever he be that Shall not make delivery of this Book, according to the true meaning of this Order, Shall forfeit for the first Offence Ten pounds of lawfull English money, the one half to the Lord of this Manour, the other half to y^e^ Jury that Shall have this book kept from them, and if the Said Foreman, that hath y^e^ Said book, Shall not make delivery of the Said book within Three Weeks next after the Said Court to y^e^ Next Foreman before Sufficient Witness and y^e^ Witnesses to be of good name that the Foreman So offending to lose all his Mineral Goods and be bannished the Occupation for ever.

66. *Giving of Pitches.*—FURTHER it is Ordered an agreed, that if any Officer Shall give any Old hole, Pitch, Gribb, or Grove, that is not lawfull according to the Customes in that behalf, the Said Officer before he make any Such Gift of any Such Place, he Shall go to the Said Pitch, Grove, Gribb, or Old hole, to See the unlawfulnesse of the Same, and to call Sufficient Witnesses to See the unlawfulness of the Same place or else the gift not to be lawfull.

67. *For y^e^ meeting of the Minerie Grand Jury.*—ITEM it is further Ordered and agreed, that if any Minerie Grand Jury, after the Publishing of this Order, Shall agree and appoint any meeting to take Evidence, and to determine of any Controversies, and that they and every of them Shall observe their meetings, according to the time and hour appointed, by the Said Jury for the time being, and there to give their attendance, and not to depart untill the either give up their Verdict, or appoint another meeting, without they are hindered by God or y^e^ King, upon pain to forfeit every man So offending five Shillings to be levyed of their Minerall Goods, without any further Seasing of Court; and y^e^ Lead Reeves to give their attendance at the Same times, under y^e^ like pain of five Shillings, a man to be levyed of their Goods also (as is aforesaid) these forfeitures to be twelve pence for the Lord, and the other four Shillings for the rest of the Jury there attending.

68. *None to fetch Oare under y^e^ Earth, after pins and bounds be known.*—WE DO also Order that whosoever he or they be, that Shall take or fetch any Oar under y^e^ Earth, under Colour of Title, y^e^ bounds and Marks being known, and pinned by indifferent men according to y^e^ Old and Ancient Custome, whosoever he or they be that Shall offend, So offending Shall loose all his Mineral Goods and be bannished y^e^ Occupation, except he or they Shall be Licenced to do the Same by Verdict of a Jury within this Manour, or if any Workman, or workmen, having Ridd his or their own Ground, and claiming y^e^

benefit of y^e^ breast of Oar by vertue of his possession, and no man likely to come down, & put him back, it Shall and may be lawfull for any workman, or workmen to go forward with the Said brest of Oare, being Licenced as aforesaid, and not Otherwise provided that this o^r^ Order doth not Extend but in y^e^ length of y^e^ ground, as forth & back in the Chine or Course of Oare when any workman doth happen to find the Same.

69. *When 2 Groves be Struck togeth^r^, they both cease working.—Made void.*—ITEM we do Order and agree that whensoever it doth happen that two Groves shall be Stricken together under the Earth, they both Shall immediately cease working, except the whole Partners on both Sides do agree upon the Marks and bounds of the Said places, and if it happen there can be no agreement between themselves, it Shall be lawfull for any partner on either Side, to repair to y^e^ Minerie Jury, if there be any in being, if there be none, then to go to y^e^ Steward, or his deputie for the time being, and crave a warrant for the Trial of the matter, in Controversie, and by Vertue of the Said Warrant, the Store Bailiffes, or Lead Reeves, or one of them Shall Set in Plumbers & Viewers to plumb, and View the said Groves, and to Swear a Jurie of twelve men, for the Trial of y^e^ matter in Controversie, and the Plumbers to give Evidence to y^e^ Said Jury, of what Shall be given them in charge, by vertue of the Said Warrant from the Steward, And if any man Shall do contrary to this Order, he Shall lose all his Minerall Goods, and Shall be banished the Occupation, And if the Steward, Store Bailiffe, or Lead Reeves Shall neglect their due performance of their Office herein, Shall forfeit five pounds, the one half to y^e^ Lord, y^e^ other to y^e^ partie grieved.

John > Roules	Jo: O Phelps
John ꟻ Ring	John I Caufe
Rob^t^. R Phelps	Blas ⋛ Waren
John E Emblen	John > Tucker
John Moore	Henry Bowcher
John Curtis	George Franck
John I P Playster	Picqard Coliens
Thomas T A Atwood	Stephen T Bathe
John I Bathe	

CHEWTON: AT THE Minerie Court there holden the First day of May* in the Eighteenth Year of the Reign of o^r^ Sov^r^gne Lord King James &c. by Consent of y^e^ Court it is ordained by Thomas Wilcox & his Fellows, as followeth.

70. *Against false Oathes.*—WE DO ORDER and agree with y^e^ Consent of the Court that whosoever he be that Shall take a false Oath before any Minerie Jurie, and that it Shall be lawfully proved by two or three Sufficient Witnesses before a Grand Jury, he Shall forfeit all his Minerall Goods to y^e^ Lord of the Manour, and to be banished y^e^ Occupation; and further we do Order, and agree and never to be taken after for any Testimony w^th^in this Occupation, and further we do Order and agree, that whosoever he be that do receive damage by any false Oath, it Shall be lawfull for him after y^e^ partie is convicted, and proved to have taken a false Oath, to follow his Cause again before any

* 1620.

Grand Jury if there be any in being, or to procure a pety Jury to right himself of y^e^ rong that was done unto him, by false witnesse, and the Verdict that was given by the false Evidence to be utterly Void.

CHEWTON: AT THE MINERIE COURT there holden y^e^ Eighteenth day of October,* in the Year above written it is ordained by John Moore, and his Fellows, as followeth.

71. *Against fetching of Oare under Colour of Title beyond y^e^ bounds.*—We do Order that whosoever he or they be that Shall take or fetch any Oare, under colour of Title, the bounds and Marks being pinned, and known, both above, and under the Earth, either by indifferent men, or consent of parties according to the Old and Ancient Custome, whosoever he or they be that Shall so offend Shall be banished y^e^ Occupation Provided that this Order doth not extend but in the length of the Ground, as forth and back, in the Chine or Course where any workman doth happen to find the Same.

CHEWTON: AT THE MINERIE COURT there holden the Nineteenth day of Aprill† in the Nineteenth Year of our Sov^r^gne Lord King James, it is ordained by consent of y^e^ Court, by Robert Wilcox and his fellows as followeth.

The 69^th^ Order Confirmed & made more plain.—Item we do Order and agree that the 69^th^ Order being made by John Moore and his fellows, and Crossed by a Second Jurie, we of this Jurie do affirm the Said Order to Stand and remain, in his full Strength and vertue, only adding that in Striking together, the hole Shall be So, that men may well passe from one Grove to the Other, whereby the difference may be y^e^ better known, and this we present, as our Act and deed.

CHEWTON: AT THE MINERALL COURT there holden the Nine and twentieth day of October,‡ in the One and Twentieth Year of y^e^ Reign of our Sovereign Lord King James it is Ordered as followeth:

72. *An Order for Grand Juries to Stand in from Court to Court.*—We of this Jury, Richard Blackman and his fellows, w^th^ Consent of y^e^ Court, and the workmen of y^e^ Occupation as followeth, for as much as before this time upon Complaint of the workmen of y^e^ Occupation, the Lead Reeves of this Manour have arested y^e^ Workmen's Goods, as well groves as other things belonging to the Occupation, and thereupon by Warrant from y^e^ Steward, have to their great Labour, and pain, impannelled Juries for trial of the Said Controversies, and Complaint, and often times for want of Good and expert Workmen, have been driven to take workmen of Small abilitie, and of little knowledge in y^e^ Occupation whereby divers workmen's grievances, Complaints and Causes, have not been fully Examined and desided, according to y^e^ Custome, and true meaning of y^e^ Occupation, and truth of y^e^ Said Complaints and Controversies, not only to y^e^ Scandal of y^e^ Officers, and workmen of y^e^ Occupacō but also delay of Justice; wherefore we of this Jury with Consent of this Court, and workmen p^r^sent, do Order & agree that from

* 1620. † 1621. ‡ 1623.

henceforth, every person, and persons that will have any Triall for any Minerall Cause or Causes whatsoever, only Causes in the behalf of y^e^ Lord excepted, according to y^e^ Customes, and Orders of the Hill within this Libertie, Shall deliver unto y^e^ Lead Reeves, or one of them that Shall make the Arrest, his Bill to Shew the Cause of his Complaint, and four Shillings and fourpence for his Triall, & the Lead Reeve Shall Summon y^e^ Jury in being to trie y^e^ Said Cause and if any man Shall Compound, and take up his Fee again before his Triall, the Lead Reeve Shall deliver up four Shillings, and keep four pence, for his own Fee, and for y^e^ more Judicial hearing, and proceeding of every cause as aforesaid, we do order that all ensueing Grand Juries, Shall Stand in from Court to Court, always provided that every Grand Jury, Shall make and deliver presentment for every Cause, as Soon as they have received full Evidence for y^e^ Same and this we present as our Acts and Deeds. Richard Blackman & his Fellows.

AT THE MINERALL COURT holden at Chewton, y^e^ fourteenth day of October Anno Domini 1624.

73. *For Cobbling of Oare.*—WHEREAS great complaint was made to us of divers misdemeanors done to diverse workmen of this Occupation, by those that do cobble Oare out of Old Barhens, and divers heaps of Oar ar Cobbled as it doth appear by Evidence given unto us of this Jury, and done by those that are no workmen but Children, whereby there is no form^r^ Order to punish Such Offenders, wherefore we of this Jury do order and agree, with y^e^ Consent of the workmen of this Occupation, that henceforwards no workman of this Occupation Shall Cobble any Oare w^th^in this Libertie, nor Suffer any of his Children, or Servants to Cobble any Oare within this libertie, whosoever Shall be found to Cobble or to Suffer his Children or his Servants to Cobble any Oare, So y^e^ Oare be to y^e^ Value of Twelvepence, if the Children or Servants be not workmen, the Said workman Shall be bannished y^e^ Occupation, and the Said Children or Servants Shall not be admitted to be workmen, nor to have any benefit within this Libertie as a workman, but by Licence of a Minerie Jury; and whosoever Shall be found to buy any Such Oare within this Libertie, y^t^ Shall be Cobbled and Shall not call y^e^ Lead Reeve to have y^e^ Sight thereof, before he doth make use of y^e^ Said Oar, he Shall forfeit for his first offence Twenty Shillings, y^e^ one half to the Lord y^e^ other half to the partie which Shall prove it against him, and for y^e^ Second Offence in the like kind, he Shall lose all his Min^r^ll goods, and be bannished y^e^ Occupation, and any Such Oare Being So cobbled, y^e^ Lead Reeve upon Sight thereof Shall Seize upon y^e^ Said Oare to y^e^ Use of y^e^ Lord as Fellon's Goods; and further if any man Shall endeavour to prove in y^e^ behalf of y^e^ Lord and himself, against any man that Shall buy any Cobbled Oare, he Shall prove it by one Witness besides himself.

74. *For entering Orders in this Book before they give their Sev^ll^ pr^sentm^te^.*—WHEREAS there was a former Order made by John Moore and his Fellows y^e^ Fourteenth day of February Anno 1620, concerning halfsmen, and other Servants, and y^e^ Said Ord^r^ is not entered in the Books; Wherefore we of this Jury do confirm the aforesaid Order, to Stand in force and Effect, and have Entered it* into one of y^e^ aforesaid books, and further we do Order, that if any ensueing Grand Jury, Shall henceforward make any Order, for the

* No. 75 order.

good Government of y^e^ Occupation, according to the Custome they Shall Enter it before their General presentment given in Court, or cause it to be entered at y^e^ Court in the aforesaid Books.

75. *By those y^t^ keep halfmen, or oth^r^ Servants, Shall Entr their names in y Store bailiffe's book.*—WHEREAS of late it was found by the Oath of John Hiltes that he was halfsman unto one Jeffory Flower of Norton, althō it was openly Seen that y^e^ Said Hiltes did Sell, Exchange Lett, and Sett, Pitches and Groves, at his pleasure divers Years together without Controlment, and by means of that Liberty and the unknown bargain between them, much damage hath happened to Some Workmen of the Occupation, by Sale of a Pitch that was wrought in another's right with great Labour and Charges, by the Space of One Year and upwards, and after y^e^ Said Flower Recov^r^ed by means of the Said Hiltes. For the avoiding of Such rude and unknown Bargains, we do from henceforwards Order and agree that after the publishing of this our Order, if any man Shall keep any half's man, or Other Servant whereby to have benefit by his pitching buying or Exchanging of any parts, pitches, or Groves, and will not allow the bargain gift or exchange, of the Said half's man or other Servant, for any parts that Shall come through their Endeavours, the Said Master Shall forthwith Enter y^e^ Contrary of y^e^ Same in y^e^ Store Bailiff's book, with y^e^ day and time, and by vertue of Warrant, from y^e^ Store Bailiffe to one of y^e^ Lead Reeves, that he make Proclamation according to y^e^ Entry, at three of the chiefest working Places within this Libertie, the Store Bailiffe to take for y^e^ Entry, and y^e^ Said Warrant fourpence, & y^e^ Lead Reeve for proclaiming it eight pence. And what Master doth not according to this our Order, what Bargain, Gift Exchange or Sale Soever he maketh Shall be good against the Said Master, and y^e^ Store Bailiffe to bring his book to every Minery Court, and there openly to read every man's Entrie that Shall be in that kind, upon pain of Such Orders as are alreadie made, upon Officers, for not performing their Office.

CHEWTON: AT THE MINERY COURT holden the Eighth day of May^e^* in y^e^ fourth Year of the Reign of our Sov^r^gne Lord King Charles, it is ordained by Consent of y^e^ Court by Richard Derham, and his Fellows as followeth.

76. *For Groves when they are Stricken together to cease working.*—WE of this Grand Jury, with Consent of Court, & workmen present, Do Order and agree, that from and after the publishing of this our p^r^sentment, that whensoever it doth happen that two Groves be Stricken together under y^e^ Earth, whereby men may pass from one Grove to another, they Shall both immediately cease working upon pain of banishment; any man So offending, except y^e^ Partners on both Sides, Shall agree upon both Marks and bounds, within themselves; Provided that if no agreement can be made between them, then y^e^ Workmen and Parteners of y^e^ Grove that doth Strike into y^e^ other that is in possession, Shall procure, his or their Trial within Six days, or else y^e^ first to Enter and work again untill he or they Shall be further Ordered by a Jury, and this we p^r^sent as our Act and Deed.

* 1628.

77. *Pitches lawfully made to Stand 12 months.*—And further whereas there was an Order formerly made by a Grand Jury, that a Pitch Shall Stand for three months, having therein a lawfull pair of Beams, & Forks, and a lawfull pair of Stillings, We of this Jury, do Order and agree, that Such a Pitch So made Shall Stand for Twelve months and a day notwithstanding any other formerly made concerning Pitches, and this we present as our Acts and Deeds.

CHEWTON: AT A MINERIE COURT holden there the last day of Aprill Anno Regni Regis Caroli nunc Angliæ &c. 8° Anno Domini 1632.

It was Ordered by Richard Adams and his fellows, as followeth, with Consent of y^e^ Said Court.

78. *Scandalling any Minery Jury man & not making Sufficient proof thereof to forfeit 20li.*—Whereas Sundry Grand Jurys being impannelled and Sworn, according to our Ancient Custome of Mendip, for the good Government of the Occupation of Miners, have lately been taxed for injustice, to their great trouble, vexation and disgrace, by ill disposed persons, when they have not p^r^sentments made them according to their own liking, for the better reformation of which Said abuses, and misdemeano^r^s, we of this Jury with the Consent of the Court, do Order and agree that from henceforth, if any person, or persons within this Libertie Shall Scandall any Minery Jury, or Jury man, by reproachfull Speeches, or by aresting their Minery Goods, for injustice wrongs, or Such like, and doth prosecute him or them to any other Grand Jury, and Shall fail to make Sufficient proof for Such their Suggestions to a Minery Grand Jury, holden for the time being (provided) if they have power and authoritie in themselves to Censure y^e^ Same; that he, or they So offending Shall forfeit 20li of Current money, y^e^ One half to the Lord of this Mano^r^, and y^e^ Other half to y^e^ partie, or parties grieved or to be banished y^e^ Occupation for ever,

Richard Adams, John Burge and their Fellows.

CHEWTON: The Seaventeenth day of Jan^r^y. Anno Dñi. 1632.* It is Ordered by James Hoskins and his Fellows as followeth by Consent of y^e^ Court.

79. *Witnesse warned by y^e^ Lead Reeve not appearing to give his testimony forfeit 5li for y^e^ first Summons. For y^e^ Second Contempt to be bannished.*—Item if any Workman of this Occupation, Shall be produced for a Witnesse, and be warned of y^e^ Lead Reeves or one of them to appear before any Jury to give evidence, for any Cause in Controversie & Shall without lawful Cause to be allowed by y^e^ Said Jury refuse to come and deliver his Testimony, on y^e^ day, time, and place, as he Shall be appointed by y^e^ Said Lead Reeve, or Lead Reeves, he Shall for Such Offence forfeit five pounds, y^e^ One half to y^e^ Lord y^e^ other to the party or partys grieved for want of Such Testimony, to be levyed of his Minerall Goods, according to y^e^ Verdict of y^e^ Said Jurie & if he refuse to come, at another day appointed by y^e^ Jury, and warning given him by y^e^ Lead Reeves or Lead Reeve as aforesaid, without lawfull Cause by the party So produced by Witness to be provided. for his Contempt he Shall be banished y^e^ Occupation, provided always y^t^ y^e^ partie, or partys that do

* 1633.

cause any Such person, or person to be so produced to give his, or their Testimony, Shall pay, or deliver to y^e^ Lead Reeve which Shall war^r^ne Such partie, or parties, that he may him or them where they be warned eight pence to each man for every days work that he, or they are to give their attendance; further if any person or persons be warned as a Witness in any Cause, wherein y^e^ Lord is made a partie with y^e^ Workman or workmen, then Such workman, or workmen to pay half Fees as it is ordered, between party and partie, and if y^e^ Cause be only in y^e^ behalf of y^e^ Lord for any Misdemen^r^ or wrong, or Fellony committed, or Supposed, then Such person, or persons, warned as aforesaid Shall give his or their attendance, and Testimony without Fee, according to y^e^ appointment of this our Order aforesaid under y^e^ like pain, of 5^li^ and this we p^r^sent as our Acts and deeds.

CHEWTON: AT THE MINERIE COURT holden the eleventh day of Aprill in y^e^ Ninth Year of y^e^ Reign of our Sovereign Lord King Charles, Anno Dm̃ni 1633 it is Ordered as followeth by James Hoskins and his Fellows by consent of y^e^ Court. .

80. *Free Shares to be laid out at ye Groves mouth and not carryed away.*—ITEM we of this Jury do Order and p^r^sent that every workman that hath or doth hereafter take, or work any part, or parts to the Share, in any Grove, Pitch, or ground within this Libertie Shall truly pay or lay forth, or cause to be laid forth unto y^e^ Freeman, or his Assigns, at y^e^ Grove's mouth as far as y^e^ ground belongeth to y^e^ Same Grove or Ground, his or their Free Share, and not be carryed away without the Consent of the Freeman or his Assigns, at every Sev^ll^ parting, at all and every Such Grove, or Ground, where any Such part, or parts of Oare So is wrought, or else upon just proof thereof to be made by y^e^ Freeman or his Assigns, by Sufficient Witness, unto a Jury of y^e^ Mynerall Court, for the time being, the workman, or workmen, Shall be thereof convicted, & the Freeman Shall have and enjoy his or their working part, or parts in as large and ample manner, as if he or they had never lett y^e^ Same. And further it is and Shall be lawfull for y^e^ Said Freeman or his Assigns to Sue in y^e^ Minery Court of this Liberty for y^e^ value of y^e^ proffits of Such free parte, or partes as aforesaid So carryed away or forfeited, by vertue of this Order, and y^e^ like Law if Such workman, or workmen, Shall not work y^e^ Said part, or parts to Effect, when time and Season will Serve as y^e^ Custome doth require, and Orders made and provided for and concerning wett works alreadie Established, if Such part, or parts as aforesaid be Such Wettworks; otherwise it ought to be wrought to Effect, as y^e^ Custome doth require as aforesaid, And this our Order to be in force upon the publication hereof, and this we present as our Acts and Deeds.

CHEWTON: AT A MINERY COURT holden there the 28^th^ day of October, Anno Regni Regis Caroli nunc Angliæ &c. decimo Anno Domini 1634. It is ordered, by John Burge and his Fellows, by y^e^ Consent of y^e^ Court as followeth.

81. *Suits to be forthwith prosecuted and not delayed.*—WHERAS diverse and Sundrie inconveniences do often arise amongst workmen of the Occupation, and others, by prolonging & detracting y^e^ prosecution of Suits, to men's daily vexation, and exceeding great discouragement, whenas there are Speedier means (if men will) for y^e^ desiding & ending of all manner of controversies,

ordained and established in that behalf by y^e^ Ancient Custome & Orders of Mendipp, but many men now adays little regarding those wholesome laws as afores^d^ and y^e^ Oaths of Jury men, with their care thereupon, do Suppose w^th^ themselves, that if a Grand Jury then in being, will not Serve their turns to make them p^r^sentments to their likings, that then they will not doubt, but that a Succeeding Jury will, and So deferre y^e^ prosecution of their Suits, and Trialls from one Time to another, & from one Grand Jury to another, and So perhapps for y^e^ Space of 4 or 5 Years, in which time they do oftentimes move and promote new Matters, & Suggest false Accusations, to the great trouble as aforesaid, as well of Jurymen as workmen (as lately appeared to us of this Jury). For reformation of all which Said Abuses, and Such prolonging of Suits, as aforesaid. We of this Jury do Order & agree that what person or persons So ever after y^e^ Date hereof Shall, or at any time heretofore have had any grievance, Offence, or Offences of any nature whatsoever done, or committed unto him or them, within this Liberty (knowing the Same to be done or committed) & doth not, and hath not forthwith prosecuted y^e^ Supposed Offender, or Offenders by way of Arrest, & preferring his or their Bill, or Bills, to y^e^ Grand Jury, then in being at y^e^ time of the Said Offence, or Offences so committed as aforesaid, from henceforth is and Shall be nonsuited, and he Utterly Void of his, or their Claim, Title & Suit, and not to be restored again by any Grand Jury y^t^ Shall Succeed; provided always that all Fellonys, Contracts, bargaine, or bargains, are freely Exempted, from this our Order, & this we present as our Acts & Deeds.

John Burge & his Fellows.

CHEWTON: AT A MINERY COURT holden there the 28 day of October, Anno Regni Regis Caroli, nunc Angliæ &c. Anno Domini 1634, it is further Ordered by John Burge and his fellows, with y^e^ Consent of y^e^ Court as followeth.

82. *Suits commenced in y^e^ Lord's name, to Stopp lawfull proceedings, to be effectually prosecuted.*—Whereas divers mischiefs and inconveniences do usually and now a days Very frequently more and more increase, & arise against workmen of y^e^ Occupation, by y^e^ means of Some ill disposed turbulent and factious persons which do arest men's goods, and Commence Suits in y^e^ Lord of y^e^ Libertie's name, in behalf of y^e^ Said Lord & themselves and Such like without any benefit at all thereby accrueing to y^e^ Said Lord of this Liberty, and without any Colour of any Just cause So to do, to no other intent or purpose, as it hath often appeared unto us of this Jury but only to Stop y^e^ passages of Other honest proceedings, & to deferr and prolong, those just Causes which are many times likely to go against them, disgracefully making y^e^ Said Lord as a Cloak, or Stopp Sharde for Such their dishonest Plotts and practices, when as there should be none but justly intended Suits Commenced in his Name. Now considering y^e^ p^r^mises, and y^e^ Complaints of honest poor workmen in Generall, who have had their Estates (for y^e^ most part) So unjustly intitled, and entangled as aforesaid, and earnestly desiring our Chiefest Aid and remedy what in us lyeth, to prevent any Such Enormities hereafter, We of y^e^ Said Jury with Consent of y^e^ Court do hereby Order and Agree, that whosoever hath, or doth make any Arest, or preferr any Bill, or Bills to this Grand Jury, using the Said Lord's name therein, and doth not forthwith prosecute Such his Suit Effectually, without any Causes Lingering or detracting y^e^ Same, and withall do, or

Shall not make Sufficient proof for Such his, or their Suggestions, by Such Witnesses as Shall be thought fitt by the Grand Jury in being to be without blemish of Exception, that he, or they whosoever is or Shall be found faulty, or any Ways delinquents, on y^e^ p^r^mises, Shall lose Fourty Shillings, more or less, or as y^e^ Grand Jury then in being Shall think fitt in their discretions, according to y^e^ Nature and quality of y^e^ Offence, or Offences, So committed as aforesaid, the One half of which penalty to remain to y^e^ Lord of this Liberty, and y^e^ other half to the party, or parties, So unjustly Taxed as aforesaid, and y^e^ Said Offend^r^ or Offenders, to be forthwith Taxed, & followed against by y^e^ Lead Reeves or one of them, that by y^e^ due Course of Law of y^e^ Occupation, Speedy recovery of y^e^ Said Forfeiture may be had against them without any manner of partiality whatsoever, upon pain of fourty Shillings on every Such Officer which Shall be found Negligent, in y^e^ due prosecution, for y^e^ Said Speedy Recovery thereof as aforesaid. And this we present as our Acts and Deeds.

This Order is allowed by a Succeeding Grand Jury.

John Burge & his Fellows.

CHEWTON: AT A MINERALL COURT there holden the Eighth day of Aprill, in y^e^ 11^th^ Year of y^e^ Reign of our Sov^r^gne Lord King Charles 1^st^ Anno Domini 1635.

83. *For Groves firm for Plumbers.*—WHEREAS there was great Complaint made unto us of this Jury by John Meedle, Timothy Watts, & William Salvidge Plumbers, and were required by our Warrant, to Plumb and View Certain Groves, within this Liberty, in which Service, as we are Credibly informed, they went in great danger of their lives, by reason of the insufficiencie of y^e^ Timbering and Ordering of y^e^ Said Groves. For Reformation of which dangerous abuses, W^E^ of this Jury w^th^ Consent of y^e^ Court do from henceforth Order and present, that when it Shall happen that any Variance Shall arise between Workman & workman, and Complaint made by y^e^ Workman, or workmen Plaintffs, unto y^e^ Jury for y^e^ time being for to have plumbers and Viewers, by them appointed, and Set into y^e^ Groves in question, to trie y^e^ Controversie according to y^e^ Complaint, and by the Said Jurie's Warrant directed unto y^e^ Lead Reeve, or Lead Reves and Plumbers So to do, the Said party or parties Plaintiffs, and y^e^ S^d^ party or partys Defend^ts^ Shall Sufficiently Timber or Cause to be timbered, his or their Grove or Groves, Course, or Courses, or place in question, without delay or fraud according to y^e^ true intent and meaning of this our Order as aforesaid, except he or they Shall Shew lawfull Cause to be allowed of by the Said Jury, that he, or they have done their best endeavours, and could not accomplish y^e^ Said work, according to the day and time appointed as aforesaid, y^e^ partie or parties found in default, Shall be Fined unto y^e^ Lord, and workman, or workmen grieved, Such Fine or Fines which y^e^ Jury for the time being Shall think fitt in their discretion according to y^e^ Quality of y^e^ Offence, and also Shall make the Plumbers Such amends as Shall be thought fit in their discretion as aforesaid, and this we present as our Acts and Deeds.

AT A MINERY COURT holden y^e^ 6^th^ of Octob^r^ Anno Domini 1640 It is Ordered by Richard Adams and his Fellows by y^e^ Consent of this Court & Workmen present as followeth.

84. *Imbesselling & detaining y^e Law hack. Banishment.*—WHEREAS the Ancient Instrument termed and called our Law hack, is imbessell'd detained and lost and cannot be at this time found, in our time of being Jurors, although that we have taken Course y^e Offend^r or Offend^rs being found to have the Said Instrument in his or their Custody, and Should detain the Said Instrument, or Law hack, as aforesaid after time Sett, & by Our Order declared and published, by y^e Authority of our Minerall Court to bring in the Said Hack in y^e presence of us there to make delivery of the Same, upon pain of banishment, and whereas we find by y^e Confession of Henry Tucker, a Lead Reeve formerly of this Liberty, that y^e Said Instrument called y^e Law-hack, was in his Custody, and he hath not made us any just and honest Account how he parted therewith, therefore we have p^rsented him guilty of banishment, for his wilfull careless neglect, and whereas the workmen of this our Occupacō are and may be much damnifyed by Such Loss of y^e Said Instrument or Law hack, w^ch is and Shall be allowed y^e Lawfull hack. For Reformation of which Abuses, we of this Jury do Order and p^rsent with y^e Consent of y^e Court & workmen p^rsent, that y^e Said Instrument, or Law-hack now Established & allowed, & p^rsented by us, in weight five pounds and from henceforth the Said Hack together w^th y^e Helve Shall not Exceed five pounds, neither Shall y^e Said Instrument aforesaid be less in weight than five pounds, and y^e helve in length Shall be fifteen inches belowe y^e Iron, & no more nor less, and not to exceed four inches about no more nor less within Nine inches of y^e end of the Said helve, and no other Instrument, or Law hack to be lawfull from henceforth, but only this Said Instrument, tearmed, and called the Law hack of this Liberty, by Order now Established, and that he ought not to be thrown, but according to y^e Custome and Order in that Case made and provided, and if it Shall happen that the Said Hack, or helve Shall be any ways altered or broken, no Lead Reeve, or Lead Reeves Shall presume to deliver y^e Same to be thrown by any workman, or workmen, before he have brought the Said Hack and caused it to be again made agreeable to this Our Order in the p^rsence of y^e Jury for the time being. Any Lead-Reeve offending in y^e p^rmises, Shall forfeit for every Such Offence Ten pounds, y^e one half to y^e Lord, and y^e Other to y^e partie, or parties grieved. AND further it is Ordered, that y^e Said Instrum^t aforesaid called our Law hack, Shall be Safe kept in y^e Custody of One of y^e Lead Reeves, to y^e end to Serve for y^e Use of y^e workmen of this Occupation, and y^e Lead Reeve which shall have y^e Said hack in his Custody, Shall deliver y^e Said Hack to y^e next Lead Reeve, when he Shall resign his Office of Lead Reeve upon pain of Ten pounds as aforesaid, and if he Shall detain y^e Said hack four and Twenty hours, after he Shall be appointed to deliver y^e Same by Order of y^e Jury for the time being, and be lawfully warned to deliver y^e Same according to their Order, he or they So offending Shall be bannished y^e Occupation.

THE Fourteenth day of Aprill, 1653.

85. *Pitches to Stand 12 months & a day.*—WHEREAS at a Min^ry Court holden for y^e Lord of this Liberty y^e 8^th day of May, in y^e 4^th Year of y^e Reign of our lat Sov^rgne L^d King Charles, by Consent of this Court it was Ordered, by Richard Derham Foreman & his fellows, y^t a pitch made Shall Stand for 12 months & a day. We of this Jury, with y^e Consent of y^e Court do approve of and allow y^e Said Order, and farther we Order, y^t if Such a pitch So made,

be not within Six days after y^e^ 12 months & a day, in Sufficient Reparations, w^th^ a pair of beams and Forks, & a pair of Stouds or Stillions, apparent above Ground, that then every Such Pitch wanting Such reparations, and being not in that Condition, Shall be utterly Void.

86. *For Cobbling Oare.*—WHEREAS there is great Complaint made unto us of this Jury, against Such persons which do Cobble Oare, and under that p^r^tence do divers times pick and Steal from y^e^ Workmen & Adventures that which they have justly, and truly laboured for, moreover we are credibly informed that these persons do not only pick and Steale from y^e^ Workmen, but do also wrong y^e^ Lord, or Lords of their duty in regard he or they do not dare to Lott it unto y^e^ right Lord, in regard their unjust practices, in picking and Stealing may be y^e^ Sooner discov^r^ed and as Some informe it is Seldome Lotted unto any Lord, by which means y^e^ Workmen of this Occupation are much abused, & y^e^ Lord, or Lords much wronged. For Reformation of Such abuses and unjust dealings done by y^e^ Said Cobblers, WE of this Jury do hereby order, and do give full power Licence and authority unto every workman & workmen, and Adventurer, as well as y^e^ Officers of this Liberty, to Seize on any Cobbled Oare, and take it into his or their Custody, & detaine it as Fellon's Goods untill y^e^ next weigh day, and then they are to deliver it into y^e^ Custody of y^e^ Officers, or One of them, and y^e^ Said Officers, or Officer are to arest y^e^ Cobblers, or Cobbler, on Suspicion of Fellony, and to bring him or them, unto a just Triall for y^e^ Same and if in Case they cannot make it appear they came by it honestly, by examining he or they Shall be dealt with as Fellons, according to a former Order, in that Case made and provided. And further we do Order that if any Dealer within our Occupation, do from henceforth buy any Cobbled Oare which Shall be raised out of this Liberty, and Shall not first acqua ĩt y^e^ Lead Reeves, or One of them, what Sum, number, quantity and weight it is of, he Shall for y^e^ first Offence forfeit unto y^e^ Lord Twenty Shillings and if he Shall be found Guilty of y^e^ like Offence again, in breach of this Order he Shall be bannished y^e^ Occupation, and this Order Shall be in it's force, for y^e^ Workmen to take y^e^ benefit thereof, after y^e^ first day of June next ensueing the date hereof unto y^e^ which we have Subscribed our hands the 12^th^ day of May Anno Domini 1653.

87. *Altering the List of Jurors Names.*—WHEREAS it hath been y^e^ Unjust practice of y^e^ Steward of the Mynery Court of Chewton Mendipp in these latter times, to alter the List or names of Jurors returned by y^e^ Lead Reeves, on the day & houre appointed, according to their Warrant to Summon a new Court twice a Year, agreeable unto y^e^ Custome and for as much as the Said Lead Reeves have done their duty in warning Sufficient and able knowing workmen of this Occupation, and So have returned them, upon their List. the Said Steward hath presumed to disappoint which he pleased, and to put in others which are no workmen nor adventurers neither do regard y^e^ Occupation, but wish y^e^ Ruine thereof, rather than y^e^ Publique Good, by which means, the body of this our Occupation, is disgraced, and it is much to be feared that the workmen & adventurers do, or may Receive much dammage thereby, and whereas by Ancient Custome the Occupacõ ought to be Ordered and governed by discreet Workmen of our Occupacõ being Miners and Adventurers. For Reformation of Such abuses, WE of this Jury do Order,

and make this decree that from henceforth the Lead Reeves or either of them, Shall upon receipt of any Warrant, to Summon, and warne a New Court according to their Warrant the day and houre appointed, the Said Lead Reeves Shall return Suffient, and able knowing workmen, and adventurers of y^e^ Same Occupation, and none Others, to y^e^ Number of four and Twenty persons, of which there ought to be Sworn three and Twenty, & the Said Lead Reeves, or one of them, or their assigns Shall proclaim their List at the Mineries of this Liberty, the Weigh day before y^e^ Court, or on the Court day in y^e^ Morning, by Nine of y^e^ Clock of the Said day before the Court house door, Shall publish y^e^ Said List or Names of y^e^ Jurors returned, and after Such publication, if the Said Lead Reeves or either of them do presume to alter the Said List, he Shall forfeit for every man's name he Shall presume to Alter, Twenty Shillings, the one half to y^e^ Lord of this Liberty, and y^e^ other half to y^e^ prosecut^r^ which Shall make first proof thereof. And further we do Order if the Said Steward for y^e^ time being do from henceforth alter y^e^ Said List of men's names as aforesaid, but that he Shall Swear them in Order as they are returned the Said Steward Shall be disabled to bear any Office in this our Occupation, Provided always if y^e^ Said Steward doth make an Arest, against y^e^ partie, or parties, which he doth except against, and exhibit a Bill unto the Jury, and prove his exceptions good and lawfull, it is and Shall be Lawfull for him So to do, if he doth Shew & prove just cause as aforesaid, otherwise he Shall be lyable to be fined, as y^e^ Jury for y^e^ time being Shall think fit in their discretion, according to y^e^ quality of y^e^ Offence done to the Partie, or parties wronged; if the Said Steward doth not give his attendance on y^e^ day he Shall appoint y^e^ Minerall Court by his Warrant as aforesaid which Shall be by Nine of y^e^ Clock in y^e^ Morning of y^e^ Said day and if he Shall not attend between y^e^ houres of Nine and twelve of y^e^ Clock in y^e^ morning to Swear the Said Jury, he Shall forfeit for every Such Offence Five pounds, y^e^ One half unto y^e^ Lord of this Liberty, and y^e^ Other half unto y^e^ Poor of y^e^ parish of Chewton Mendipp. And this our Order to to be in force upon y^e^ publication hereof, that all persons whom it doth or may Concern, may take Notice, thereof, to put this our Order in Execution, at y^e^ Next Minerall Courte, And unto this we have Subscribed our hands y^e^ 5^th^ day of October in y^e^ Year of our Lord God 1654.

AT A MINERALL COURT holden y^e^ 18^th^ day of June in y^e^ Year of our Lord God 1657, it is ordered by Andrew Bawler & his Fellows as followeth.

88. *Stopping Ruinated holes.*—WHEREAS there is complaint made unto us of this minerall Grand Jury, of many Ruinated holes within this Libertie which lie dangerous both for man and beast, many of which have been a long time So ruinated, and y^e^ Owner or Owners thereof are are not to be known, nor known for y^e^ present, whereby he or they may be Ordered according to y^e^ Former Orders in that Case made WE of this Jury for Reformation of Such Abuses do Order and make this decree, that from henceforth it Shall be lawfull for y^e^ Lords Officers and Tenants, & Surveyors of y^e^ High ways within this Libertie, to enter upon y^e^ Said Ruinated hole, or holes, three days in every Year hereafter and beat him, or them down, for y^e^ preventing of further danger, both of man and beast; which days appointed, Shall be Yearly hereafter on y^e^ Tuesday, Wendsday, and Thursday in y^e^ Trinity week, and at no other time except there be Sufficient Cause Shewn to y^e^ Contrary, unto the Minerall

grand Jury for y^e^ time being; And farther Ordered by them, in regard Trinity Monday at y^e^ farthest all workmen and Adventurers, ought to repair his or their works, and to keep them Tennantable, as the Custome doth require; and further we do Order that if y^e^ Owner, or Owners of any Such ruinated hole or holes, be known and have warning given him or them, by y^e^ Lead Reeves, or Store Bailiffe, or either of them to repair it, or fill it to prevent further Danger as aforesaid, and if he, or they Shall refuse So to do, and not repair nor fill y^e^ Same, within 20 days after Such warning given him or them, if y^e^ time & Season of y^e^ Year will permitt him or them to work to do y^e^ Same, he, or they Shall be liable to pay y^e^ penalty, of y^e^ Order formerly made concerning Ruinated holes; And unto this we all agree, and have Subscribed our hands, y^e^ day and Year first above written.

AT A MINERALL COURT holden y^e^ 18^th^ day of June, in y^e^ Year of our Lord God 1657, it is Ordered by Andrew Bawler and his Fellows, as followeth.

89. *For taking up Fees once laid down.*—WHEREAS there is an Order formerly made by Richard Blackman and his Fellows, for Grand Jurys to Stand from Court to Court, and whereas in y^e^ Said Order, it is and may be lawful upon an agreement for y^e^ Plaintiffe to take up his or their Fee as it is in that Order Expressed, WE of this Jury do further Order if any Such agreement be made from henceforth, it Shall be made before, he or they do joyn Issue for his or their Triall, and before y^e^ Jury for y^e^ time being hath appointed y^e^ day & have Issued out their Warrant for y^e^ Triall thereof, and if Such agreement be made after, the Fee Shall be forfeited to y^e^ Jury which do and Shall meet, at y^e^ day & time, & place appointed as afores^d^.

AT A MYNERY COURT, holden at Chewton the Fifteenth day of October in y^e^ Year of our Lord God 1658, it is Ordered by John Radford & his Fellows as followeth.

90. *For carrying y^e^ Water in Row pitts.*—WHEREAS there was Complaint made unto us of this Jury for y^e^ Waters drawing in Row Pitts to have y^e^ Workmen to work Orderly for the publique good of y^e^ Lord and workmen, wherefore we of this Jury do order, and make this decree, that y^e^ Partners and Owners of every Several Grove there, Shall be at y^e^ Charge of carrying their Water in a Sufficient Stream, where they do draw y^e^ Same to y^e^ Main Stream, or Streams which runneth to Chewton Minery, at their own Sev^ll^ and particular Charge, upon pain of fourty Shillings, the One half to the Lord, y^e^ Other half to y^e^ Party grieved, y^t^ Shall justly prove y^e^ Same and no man Shall deny him or them to carry or convey y^e^ Same away under y^e^ like Pain. And we do further Order that y^e^ Main Stream or Streams Shall be Sufficiently repaired, at y^e^ Charge of y^e^ Lord and Workmen, according to y^e^ Judgment of y^e^ Jury, for y^e^ time being as they Shall Order and appoint, and unto this we all agree and have Subscribed our hands, y^e^ day and Year first above written.

AT A MINERALL COURT holden at Chewton the Twelfth day of October in y^e^ Year of our Lord God 1660, it is Ordered by John Radford and his Fellows as followeth.

91. *For ye Officers Fees.*—WHEREAS we of this Jury do Order and p^r^sent, what is and Shall be due unto every Officer for ye Accustomary Fees of this Liberty which is as followeth, First, to y^e^ Lead Reeve which maket an Arest, 4^d^. and to y^e^ Store Bailiffe for recording y^e^ Same Arrest 4^d^. and no more and to y^e^ Lead Reeve for Summoning y^e^ Jury 4^d^. and no more, and to the Steward for y^e^ Copy of any Order 4^d^. & no more, & y^e^ Copy of Any p^r^sentm^t^ 4^d^. and no more, and for his warrant annexed to any p^r^sentment 12^d^. and no more, & for his warrant upon Oath to grant Proclamation, according to y^e^ Order in that case made 4^d^. and no more, and to y^e^ Lead Reeves for proclaiming the Same 4^d^. and no more, and to y^e^ Store Bailiffe for Recording y^e^ Same 4^d^. and no more, and to the Steward if he grant Execution after y^e^ time is expired agreeable to y^e^ Order 12^d^. & no more, and to y^e^ Lead Reeve for Levying, or giving any Execution upon any p^r^sentment, by Vertue thereof, annexed with y^e^ Stewards Warrant of Execution 12^d^. and no more, to y^e^ Lead Reeve, or Lead Reeves for taking of Security by Order from y^e^ Jury for every Severall Arrest 12^d^. & no more that if it doth happen that there are Sundry persons concerned in that Arrest Yet y^e^ Lead Reeve's Fee is but 12^d^. to answer y^e^ whole arrest, to y^e^ Lead Reeves for bringing y^e^ Law hack but 4^d^. to be paid by him which demandeth y^e^ Same, and to y^e^ Store Bailiffe if y^e^ Law hack be thrown either by Consent, or Order of y^e^ Law of y^e^ Occupation, his Office is to be p^r^s^t^ & there to record by whom y^e^ Said Lawhack was thrown, and against whom and in what place of this Libertie, & how far it was thrown So, and his Fee for So doing Shall be 4^d^. and no more, to y^e^ Lead Reeve which Shall give any Pitch or Old hole which is lawfull to be given according to y^e^ true intent of y^e^ Order in that case made, 2^d^. and no more, to the Lead Reeves for entering of any Bargains, Mortgages or Contracts in his book but 2^d^. and no more, and to y^e^ Store Bailiffe for recording y^e^ Same in his book 2^d^. and no more. Provided always if y^e^ Arrest, or Arrests be made wholly for y^e^ Lord, then no Officer Ought to take any Fee in y^e^ Execution of his or their Office as aforesaid, or if y^e^ Lord be made a partie with y^e^ workman, or Workmen, then they Ought to take but half Fees, as aforesaid, And if any Officer Shall from henceforth take directly or indirectly any more Fees, for y^e^ Executing of his Office than is in this our Order, and p^r^sentment particularly Set down, Specifyed and declared, he Shall be utterly made Void to bear any Office within this Libertie any more. And unto this we all agree and have Subscribed our hands, y^e^ day and Year first above written.

AT A MINERALL COURT holden at Chewton the Twelf day of October in y^e^ Year of our Lord God 1660, it is Ordered by John Radford and his Fellows as followeth.

92. *For Jurie's Fees upon Summons.*—WHEREAS there are former Orders that do express what Fees are due to y^e^ Jury, as is Set down in y^e^ Said Orders, which we of this Jury do approve of, to be agreeable to y^e^ Custome, And do farther Order, that if any person, or persons do desire or Require a Speedy Triall, between y^e^ Said Jury's appointed meetings, or publique day of keeping y^e^ Minerall Courte, the Said Plaintiffe, or Plaintiffes Shall deposite into the Lead Reeve's hand 4^d^. for y^e^ Summons and Fee of every Jury man, which Shall be Sufficient to trie y^e^ Cause, and then y^e^ Jury, or Jurymen, ought to meet at y^e^ Court house; And if any Jury man So Summoned Shall refuse to come to do his Service, his 4^d^. being paid, or tendered unto him by y^e^ Lead

Reeve, or Lawfull deputy, and notice given him of y^e^ day and houre appointed by y^e^ Foreman, or Plaintiffe, or Plaintiffes, he that Shall not come to do his Service as aforesaid, Shall forfeit for every Such Offence 5^s^. the One half to the Lord, the Other half to y^e^ Partie, or parties grieved, except he Shew a Sufficient Cause to the rest of y^e^ Jury at their next meeting. Provided always when y^e^ Jury hath tryed y^e^ Cause y^e^ 4^s^. due to them for their accustomary Fees ought to be paid, besides their 4^d^. to each man which they Received upon their Summons. And unto this we all agree.

AT A MINERY COURT holden at Chewton Mendipp y^e^ 10^th^ day of Feb^ry^ in y^e^ Year of our Lord God 1661, it is Ordered, by Richard Adams & his Fellows as followeth.

93. *For drawing y^e^ water at Pucksudds.*—WHEREAS there hath been complaint made unto us of this Minery Grand Jury by William Redman, of great wrongs and abuses done unto him by Severall disorderly persons, as touching a washing Pond, or Pool, and another watering place for Cattell, both lying and being adjoyning to a place commonly called by the Name of Puck Suds, which Said Ponds, or Pools, as doth appear unto us of this Jury, have been made at y^e^ Proper Cost, and Charge of the Said William Redman, but for y^e^ publique Good as well of y^e^ rest of the Borderers as himself; And further it doth appear unto us that the Said Places do not hinder y^e^ buddling place, of any water that usually did come to y^e^ Said place, but rather help them to more; wherefore we of this Jury taking y^e^ p^r^mises into our Consideration, do Order and make this decree, with y^e^ Consent of y^e^ next ensueing Court, that if any person or persons whatsoever belonging to this Occupation Shall presume to draw any Water, or cause to be drawn, or wash with that Water there, out of either of y^e^ Said Pools, at any time but what doth naturally run in it's Course, without y^e^ Special Licence and Consent, of y^e^ Said William Redman, or his Assigns, Shall forfeit for y^e^ first Offence 20^s^. the One half to y^e^ Lord of this Liberty, and the Other half to y^e^ partie grieved, that Shall make just proof thereof, and for y^e^ Second offence 5^li^. to be paid as afores^d^ and if he or they Shall be found to offend in y^e^ like nature y^e^ third time, they Shall be banished from this our Occupation, always Provided the Said Offence or Offences, be found by Verdict of a Grand Jury. And to this Our Order we all agree and have Subscribed our hands.

AT A MINERALL COURT held at Chewton Mendipp y^e^ 24^th^ day of March anno Dmñi 1667, it is Ordered by y^e^ Said Court as followeth.

94. *For giving ye Officers an Account what Oare they make out.*—FOR AS MUCH as Complaint hath been made unto us of this minerall Grand Jury, by y^e^ Officers belonging unto the Lord of this Liberty, that they do conceive and have a great Suspition, that there are Sev^ll^ ways and means Used whereby y^e^ Lord of the Libertie afores^d^ is deprived of his just right, & privileges arising and becoming due unto him; by vertue of y^e^ Laws and Customes of the afores^d^ Liberty. For prevention whereof for the time to come, we of this Jury as aforesaid conceiving that it cannot be prejudicial to any honest minded workman, or any others, do Order and agree, that all persons whatsoever working within y^e^ Liberty aforesaid, Shall give a just and honest Account of all his, or their Minerall Goods, arising or being Landed within y^e^ Said Liberty, and

if any person, or persons whatsoever as aforesaid Shall refuse So to do being thereunto called or requested, by any lawfull Lead Reeve, or Lead Reeves, or Store-Bailiffe, within Ten days next after any Such goods made out, Shall forfeit for y^e^ first Offence y^e^ Sum of 10^s^. the One half thereof to the Use of y^e^ Lord, and y^e^ Other half to the partie complaining, proof being first made to y^e^ Grand Jury for y^e^ time being, either by Confession of y^e^ party Questioned, or by y^e^ Oath of two or more Sufficient Witnesses. For y^e^ Second Offence the partie offending as aforesaid Shall forfeit all his or their Goods as afores^d^ to y^e^ Uses afores^d^. And for y^e^ third Offence y^e^ partie So offending as afores^d^ Shall be banished y^e^ Occupation for Ever.

95. *A new Order concerning Striking of Groves together & odd Ground.*—For as much as there hath been a very great and considerable discovery of Oare lately made, at or near a certain place upon Mendip called Hadbarrow, within this Liberty, where none or very few perfect Rakes, Courses or Chines, are as Yet found, but workmen and Adventurers there are Yet wholly confined to their Respective 18 Foot of their first Pitches, & whereas many differences & troubles do daily, & more and more arise between partie and party to the great prejudice both of Lord and Workmen, as also to y^e^ great trouble of the grand Jury of this Liberty for y^e^ time being, by the disOrderly Striking of Groves together there under neath y^e^ Earth and otherwise notwithstanding many good and laudible Laws formerly made in that behalf, all which Laws we of this Jury do really approve of. For y^e^ better Order and Government of y^e^ Occupacō within this Liberty for time to come, We of this Jury do Order and agree, and be it So Ordered and agreed, that from the 7^th^ day of this Ins^t^ month of May, if any person, or persons do or Shall Sink any Grove Lawfully within y^e^ Ground of his or their first Pitch, that then no other Workman, or Workmen, Shall make any Grove or hole by him, to Strike into his Shaft, whereby to hinder his or their work, Always provided that their Shaft be within their own Ground as afores^d^ that then any man striking together as afores^d^ Shall lose all his or their minerall Goods to y^e^ Lord of the Liberty, and be bannished y^e^ Occupation; but if y^e^ Second Worker do begin his Grove within his Own Ground, and doth Sink down and Strike to y^e^ Other underneath y^e^ Earth, in his Rake, or Course, or at the Oare in question (which may probably be found without eith^r^ Rake or Course) according to y^e^ Law, then they Shall on both Sides immediately Surcease working, in both the Said Groofes So Stricken together as aforesaid, & in all other Groofes that Shall be or then are wrought in y^e^ Right of either of y^e^ Said Pitches, untill the Title thereof Shall be tryed, or agreement made according to y^e^ Law in that behalf, under y^e^ like Penalty. And we do further Order as aforesaid, that if any man do or Shall work under the Colour of a Catch, or an Odd Ground, whereby to hinder any Elder Pitcher by Striking to them, or to fetch any Oare, which afterwards Shall be made appear, unto y^e^ Said Grand Jury, for y^e^ time being that his, or their working be within y^e^ Square of any Elder Pitchers, 18 Foot either above or underneath y^e^ Earth, and Shall presume to carry any Such Oare before Such party, or partys Shall clearly make it appear to y^e^ Said Jury that he or they have and do fetch Such Oare within their own proper Ground, and clearly out of y^e^ Ground of any other, that then he, or they So offending as aforesaid Shall likewise forfeit and lose, all his and their Minerall Goods, as afores^d^ and be bannished from y^e^ Occupacō. And we do further Order that if any neighbouring workman, or workmen, Shall fetch any Oare out of y^e^ Ground of either of y^e^ Said Groofes So Striken together as aforesaid during

the time of their Surceasing their working as afores^{d} and Sufficient proof thereof Shall be made to y^{e} Said Jury then he or they So offending as aforesaid Shall also forfeit his and their Minerall Goods as aforesaid and be likewise bannished from y^{e} Occupacõ. And unto this we all agree, and do p^{r}sent y^{e} Same as our Acts & Deeds the Sixth day of May, in y^{e} Twentieth Year of y^{e} Reign of King Charles the Second over England &c. Anno Dmñi, 1668.

AT A MINERALL COURT holden at Chewton the 5th day of May, 1670, it was Ordered and agreed upon as followeth.

96. *Summoning a Jury to forfeit xx^{s}.*—Whereas divers inconveniences, have heretofore happened and do daily arise, by reason of a Gen^{ll} Order formerly made for Summoning and Calling together y^{e} Min^{ll} Grand Jury for the Liberty of Chewton Mendip, whereby many times it So falls out that y^{e} Jurors are put to a Nonplus, and Plaintiffe & Defend^{t} or both do Suffer great Losse and Damages thereby, we of this Jury therefore having taken y^{e} p^{r}mises into our Consideration, for p^{r}vention whereof for the time to come, and for the more legall proceedings of all parties herein Contained, have agreed and thought fitt to Order & by these p^{r}sents do Order and agree, that no person, or persons whatsoever from, and after the 24th day of May next after y^{e} Date hereof Shall Summon or cause to come together the Said Minerall Grand Jury for y^{e} time being, for any Matter Cause, or thing whatsoever except hereafter in this Order Excepted, Viz^{t} in Case of Water drawing, Striking together of Groves, Fellonys, or burning places, & no otherwise; And any person, or persons, Shall hereafter Summon or warn any Jury as aforesaid Contrary to this Order, he, or they, whatsoever he, or they be, Shall forfeit and lose for ev^{r}y Such Offence y^{e} Sum of twenty Shillings to be levyed, upon his or their Minerall Goods, by y^{e} Lead Reeves or one of them for the time being, the One half to the Lord of this Liberty, and y^{e} oth^{r} half to y^{e} party, or partys grieved, and no proceedings to be had upon y^{e} Said Summons, And this we p^{r}sent as our Acts & Deeds.

AT A MINERALL COURT holden at Chewton y^{e} 8th day of July, 1671, It was contented and approved of as followeth, by us whose names ar hereunto Subscribed.

97. *M^{r}. Bush^{ll}s Order for water works.*—Whereas Thomas Bushell Esq^{r} hath (not long since) to his very great Charge and Expence, endeavoured by his Audits and Swalletts, to draine y^{e} deserted Works of S^{r} Bevis Bulmer, in Rowe Pitts near Chewton Minery in ye Forest of Mendip, which by reason of innundations, and breaches of Waters into y^{e} Said Works they Yield not the Tenth part of y^{e} Profits, which otherwise they might have done, & whereas for his better encouragement to persist in y^{e} Carrying on of So expensive and dangerous a work, tne King's most Excellent Majestie in y^{e} 14th Year of his Reign, together with y^{e} Consent of y^{e} Lords Spiritual and Temporall assembled in Parliament, did then, and there Enact, that the Said Thomas Bushell, his Exec^{r}s Admins^{r}s and Assigns Should have the full power to make Audits and Swalletts, and all Such Groves, as he or they Should think fitt, for y^{e} draining of y^{e} Said S^{r} Bevis Bullmer's deserted works in y^{e} Lead Mines in Row Pitts. and Green Oare in tne Said Forrest of Mendipp in y^{e} County of Somersett, And that y^{e} Said Thomas Bushell his Exect^{r}s and Administ^{rs} performing his Said

undertakings of dreining y^e^ Said Works or any of them by Audits Swalletts, Suffes, Draynes, or by any other Means, whatsoever, So as y^e^ Respective Myners, may work, and draw Oare without any Charge of draining & Clearing the Water, and Shall be So adjudged by y^e^ Minerall Grand Jury Court, belonging to y^e^ Jurisdiction wherein y^e^ Said Mines So drayned Shall be for y^e^ Respective Miners for Time being, & that by his and their workmanship, the Said Myners are and Shall be freed from y^e^ innundation of their Waters, he y^e^ Said Thomas Bushell, his Exct^rs^ Administ^rs^ and Assigns, bearing half y^e^ Charge of Digging y^e^ Said Oare, Shall have take, and receive one full moietie, of all y^e^ Oare that Shall be drawn, and Landed, by all and every y^e^ Respective Myners, and Undertakers there, and in all and every y^e^ Respective Shafts, Cross-Rakes, By-Rakes, or other Mines within y^e^ Said Mines of Rowe-Pitts & Green Oare, with Liberty to work the Said Mines from time to time, for Raising and getting y^e^ Oare therein, and to drive through and Sink shafts, in any Such Rakes of Ground, delivering all the Moiety of y^e^ Oare gotten in all or any y^e^ S^d^ Drifts and Shafts unto y^e^ Owners thereof, they y^e^ Said Owners paying y^e^ full Moiety of y^e^ Said Charge; And whereas Sev^ll^ of y^e^ most concerned Adventur^rs^ there, have heretofore (for y^e^ like encouragement) Subscribed their Assent to y^e^ performance of y^e^ p^r^mises, as by writings under their hands may appear, And whereas y^e^ Said work hath hitherto proved not only Very Costly and Expensive but also very ineffectuall and unproffitable; Yet notwithstanding y^e^ Said Thomas Bushell together with S^r^ Edmund Wyndham, Knight & Marshall &c. purposing and intending, by their Ingenuity and expences to Carry on y^e^ Said work accordingly; W^E^ of this Minerall Grand Jury Court for y^e^ Liberty aforesaid for y^e^ time being together with y^e^ Consent, and approbation of Sev^ll^ of y^e^ Adventurers there whose Names are or Shall be Subscribed as aforesaid, do really conceive & hereby declare & allow, that from henceforth they y^e^ Said Thomas Bushell, & S^r^ Edmond Wyndham, their Exect^rs^ Administ^rs^ & Assigns, Shall have, Receive, take and Enjoy (bearing halfe the Charges as aforesaid) One full Moietie of y^e^ Oare, that Shall be drawn, and Landed, by all and Every y^e^ Sev^ll^ & Respective Miners and Undertakes, there and in all and Every y^e^ Respective Shafts, Groves, Rakes, Veines, Pipes, flat Crosse Rakes, By Rakes or other Mines, within y^e^ S^d^ Liberties, & precincts of Rowe pitts and Green Oare where, and in Such places only as they y^e^ Said Thomas Bushell & S^r^ Edmond Wyndham, their Execut^rs^ Admins^rs^ or Assigns, Agents or Workmen Shall make it appear to y^e^ Said Minerall Grand Jury Court for y^e^ time being, that they by their Ingenuity, Labour and Expences, have drained y^e^ Same; And further W^E^ Seriously Considering y^t^ y^e^ Premises and y^e^ Work in question being (by God's blessing) brought to be Effectuall, and that y^e^ advantages thereof will then redound, and accrue, to a generall Good; W^E^ therefore (So much as in us lyeth) do declare, allow and Confirm, unto the Said Thomas Bushell, & S^r^ Edmond Wyndham, their, and eith^r^ of their Exect^rs^ Administ^rs^, One full Moiety of y^e^ proffitts afores^d^ by and under y^e^ Terms and Conditions afors^d^ And Shall be ready to give them any lawfull Encouragem^t^ and Assistance therein.

AT A MINERALL COURT holden at Chewton y^e^ 10^th^ day of Aprill in y^e^ Year of our Lord God 1673, it is Ordered as followeth.

98. *For what Causes a Jury Ought to be Summoned.—Confirmed.*—WHEREAS there hath been a former Order made, by Lawrence Foreshaw, and his Fellows,

concerning y^e^ Summoning of y^e^ Jury, and for what Causes a Jury Ought to be Summoned, which we of this Jury do allow of also, only adding, if y^e^ Jury for y^e^ time being doth meet once in Three Weeks according to y^e^ Usual Course. otherwise it may be lawfull to Summon y^e^ Jury upon any Triall.

AT A MINERALL COURT holden at Chewton y^e^ 10^th^ day of Aprill in y^e^ Year of our Lord God 1673, It is Ordered as followeth.

99. *Empowering Lead Reeves to Summon Plaintiffe & Defendant.*—WHEREAS there hath been a Former Useage among y^e^ Workmen, of this Occupation, that when their Goods have been Arrested, for any Debt, or any Misdemeano^r^ y^e^ Defendant not being Willing to pay his Just Debt, or to answer Such Misdemeano^r^s as he or they are, or may be Guilty of; when their Minerall Goods are arrested will refuse to come to y^e^ next meeting of y^e^ Jury, untill there is an Express Warrant from y^e^ Jury on purpose to delay men, and keep them from their Just Right; For Reformation of which abuses, we of this Minerall Grand Jury, do Order and agree, that y^e^ Lead Reeves or either of them, when they Shall make any Arrest, or Arrests upon y^e^ Minerall Goods of any person, or persons, that he, or they Shall give notice to y^e^ party, or partys plaintiffe, and Defend^t^ to appear, at y^e^ next Generall Meeting of y^e^ Jury, and they are to take Notice thereof, as if there were a Warrant granted from y^e^ Jury, to y^e^ Intent they may Joyn Issue for a Triall, y^e^ Second meeting, & to do y^e^ like upon Summons, And to this we all agree and have Subscribed our hands.

AT A MINERALL COURT holden at Chewton the 8^th^ day of October Anno Domini 1675.

100. *Against Such as pick and Steale Oare.*—WHEREAS great Complaint hath been made unto us of this Minerall Grand Jury, that many times poor Workmen having ventured their Estates and lives, to get Some Oare, it is no Sooner Landed, but it is Stollen; whereby it is not only a great Damage Losse, and discouragement to poor Workmen, but also prejudiciall to y^e^ Lord of y^e^ Manno^r^ and because of their walking at Unseasonable houres about their unjust Dealings, Sufficient proof cannot easily be made against Such persons, that do pick and Steal Oare. It is a very hard matter for any Law to proceed against them, w^ch^ doth y^e^ more encourage y^e^ evill intents of Such Audacious Rogues which make it their practice to pick and Steal from poor Workmen: WE having therefore taken y^e^ p^r^mises into our Serious Consideration do Order and agree, with y^e^ Consent of y^e^ Court, and next ensueing Grand Jury, that if any person, or persons Shall after y^e^ publishing of this our Order be Suspected to have Stollen any Oare, he or they Shall make it appear to y^e^ Minerall Grand Jury for y^e^ time being, where Such Oare was Landed, and how they came by it, otherwayes he, or they Shall be banished y^e^ Occupacō. And further we do Order and agree that if any Dealer Shall buy any Oare, that Shall be raised within this Liberty, and brought in Baggs, or upon Horses, or at Unseasonable times, Shall forthwith give Notice to y^e^ Lead Reeves thereof, that Proclamation may be made the Next Weigh day in y^e^ Minery, And also Such Oare to lie 10 days after proclamation, before it be beaten, or Smelted, or any Use made thereof; And if any Dealer, or Dealers do Contrary to this our Order, Shall forfeit for every Such Offence, the Sum of Ten pounds, y^e^ One half

to y^e^ Lord of this Mano^r^ y^e^ Other half to y^e^ Complainer, & to this we all agree and have Subscribed our hands, y^e^ day and Year first above written.

AT A MINERALL COURT holden at Chewton y^e^ 8^th^ of May, 1679, It was Ordered and agreed on as followeth.

101. *For pitches to Stand 12 months and a day & no longer.*—WHEREAS there hath been Complaint unto us made of this Minerall Grand Jury concerning Small Pitches within this Liberty: WE of this Minerall Grand Jury having taken the p^r^mises into our Serious Consideration, do find in our judgments that it is a great hinderance both to y^e^ Lord of this Liberty, and also to y^e^ honest Adventures, and Workmen belong to y^e^ Occupation, to have great parcells of Ground possessed with Pitches and never wrought to Effect, to y^e^ benefit of y^e^ Lord, and Workmen, but either to ly upon y^e^ Advantage of other men's Labours, or to Sell parts, or to have Free Shares or Such like, and So to keep them from time as long as they please, and many times and most frequently done by those that are no workmen of y^e^ Occupation, nor do adventure any money therein, besides many Times when Pitches are kept So long, men do not perfectly remember y^e^ time of Pitching, which may be, (and as we do much doubt is) the Cause of many false Oaths concerning Elderships, and Such like, and whereas there is a former Order, that Pitches Should Stand Twelve months and a day, and do not expressly Say no longer; but we of this Jury do verrily believe that y^e^ true intent, and meaning was that they Should be kept no longer unwrought, and another Order made Since by M^r^ Gett, and his Fellows, that doth allow them to Stand as long as men please, if they keep Timber to be Seen above Ground, both w^ch^ Orders, both which Orders, and all Others concerning Pitches, WE of this Jury do make Void, and for Reformation of Such inconveniences for y^e^ time to come, do Order and agree with y^e^ Consent of the next ensueing Court, that if any Workmen, or Adventurers, that have been taken as Tennants to any of y^e^ Four Lords Royal of Mendip that is to Say he that hath paid Lott to any of them out of his or their adventure, or have Entered their Names upon y^e^ Officers book, and given good Security for their good behaviour, according to y^e^ Ancient Custome, have any Pitch, or Pitches within this Liberty, and do put them in Sufficient Reparations, on Trinity Monday next after y^e^ Date hereof, and do take two Witnesses or more with him or them to See y^e^ doing thereof or bring them to y^e^ place within Three days after, to See that it is done, or Record y^e^ Same upon y^e^ Lead Reeve's book, and pay him 2^d^. for So doing, that then they Shall Stand Lawfull 12 months & a day and no longer. And from henceforth after y^d^ publishing of this our Order, if any Workman, or Adventurer, that hath been taken as a Tennant as afores^d^ or that hath, or doth enter his name upon y^e^ Officer's book, and give Security for his or their good behaviour, according to the Custome, as aforesaid, do make any Pitch, or Pitches within this Liberty, and do make them lawfull, with a lawfull pair of Beams and Forks, and a pair of Stowes, or Mark'd Stillions, within 24 houres after he doth break y^e^ Ground to make a Pitch, and do take with him or them 2 Witnesses, or more, to See y^e^ doing thereof, or do bring y^m^ to y^e^ place within 3 days after to See that it is done, or do record y^e^ Same upon y^e^ Lead Reeve's book within 3 days as aforesaid, that Such a Pitch So made Shall Stand 12 months and a day and no longer. But if it be not wrought to Effect within 12 months and a day, as afores^d^ that then it Shall and may be lawfull, for y^e^ Lead Reeves, or either of them, to

give it to any other workman, or Workmen, or Adventurer that will work y^e^ Same to Effect, for y^e^ benefit of y^e^ Lord and themselves, and the generall Good of y^e^ Labourers, belonging to y^e^ Occupation, except it be any Pitch, or Pitches that are next or near adjoyning to any man's Grove, or Groves that are in Working for y^e^ Triall of any Countrey, and not else; And this we p^r^sent as our Acts & deeds.

Thō: White, & his Fellows.

WHEREAS the Order afore written was made and agreed on by Thomas White & his Fellows, we of the Succeeding Grand Jury, having perused y^e^ Same do hereby acknowledge our approbacō and Allowance of y^e^ Same, and do hereby confirm y^e^ Said Order to Stand & remain Effectuall in y^e^ Minerall Law, to all Intents and purposes.

Edward Hipsley and his Fellows.

AT A MINERALL COURT holden for y^e^ Lord of the Mann^r^ of Chewton, the first day of November in the Year of our Lord 1699, It is Ordered and agreed upon by Richard Derham Foreman, & his Fellows as followeth.

102. *A new Order concerning Pitches.*—FOR AS MUCH as divers complaints have been daily made unto us of this Minerall Grand Jury, by Sev^ll^ knowing honest workmen of this Occupation, that Sev^ll^ persons now at this present time do make great Number of Pitches with Very Small Spriggs, Shoots, and other Small Sticks, which were not Yet afore Used, nor allowed of to be good by y^e^ Old ancient Workmen of this Occupation; And likewise that Sev^ll^ persons, have taken many dangerous Oathes, in Swearing that Such Pitches are Lawfull, according to y^e^ Ancient Order, & Custome of this Occupation: WE of this Jury having examined into y^e^ Premises, do find upon Examination, that there hath been many dangerous Oaths taken, concerning Pitches, and that there are many honest knowing workmen, kept of from adventuring by reason and means of Such Pitches, So made and allowed of, to y^e^ great hinderance and p^r^judice, both to y^e^ Lord and honest workmen belonging to this Occupation. For Reformation of Such abuses, & Gross Offences, to be Committed for y^e^ future, WE of this Minerall Grand Jury, do by and with y^e^ Consent of y^e^ Court, Order and agree that from & after y^e^ Twentieth day of Feb^r^y next ensuing y^e^ Date hereof, that every Pitch upon this Occupacō Shall be made lawfull, with a lawfull p^r^ of Beams and Forks, apparent above y^e^ Ground, which S^d^ Beams, & Forks, Shall be made in manner and forme following that is to Say every beam Shall be in y^e^ Cleare Three Foot in length, and every Fork Shall be in y^e^ Clear two foot in breadth, and likewise Shall be boared through, with an Auger that is full three quart^rs^ of an inch bigg, or more; And that every Pitch after the 20^th^ day of February next wanting Such Timber in length & breadth and not boared as aforesaid, or wanting a lawfull pair of Stower, or Stillings, apparent above Ground, Shall be Utterly Void and of None Effect, notwithstanding any former Order, or Orders to the Contrary; And further we of this Jury do Order and agree that what person, or persons So ever he be that Shall have any Pitch, or Pitches upon this Occupation unwrought, or untryèd Trinity Monday next Shall within Six days after y^e^ Same, and So every Trinity Monday Yearly and every Yeare, go and Open, or cause to be Opened, all and every his Said Pitch, and Pitches, to See that they and every one of them, are in Such good, and Sufficient Condition, as is before mentioned, and whosoever Shall neglect, or refuse to do y^e^ Same, that then it Shall be

lawfull for y^e^ Lead Reeve, or other Officer or either of them, to give and dispose of all and every Such Pitch, & Pitches to those that will repair and work y^e^ Same; And to this we all agree, and have hereunto Set our hands the day and Year first above written.

Richard Derham	William Blackman
Joshua Finch	William Lunbley
Stephen Blinman	Thomas Eglefield
John Burge	John Lane
Samuell House	George Cornish Sen^r^
John Hayward	George Blandon
Thomas Nickles	John Bendur
Thomas Green	John Warbler*
John Dudden	

AT A MINERAL COURT holden for the Lord of the manor of Chewton, the tenth day of Novem^r^ in the year of our Lord 1701, It is ordered and agreed upon by John Clark Foreman, and his Fellows as followeth.

103. WHEREAS there hath been a former order made by Richard Derham and his fellows concerning the gross abuses and offences of small pitches which order we of this Jury do allow of and confirm, and further we do add by this our order that what pitch or pitches are now standing and in being in any part of Row pitts Small pitts or Green Oar they being all very wett works and that the said pitches have stood many of them several years unwrought to the great damage of the Lord as well as workmen, and also have kept out several workmen, and adventurers that would work and adventure in the same. For reformation of all such abuses for the time to come we of this Jury do order and agree that all and every the said pitch and pitches before mentioned be set to work by the owners thereof in order for the full tryal of the said pitches before mentioned at or before trinity munday next with a groof or groves, in right of the said pitch or pitches And further we do order that what pitch or pitches shall remain unwrought in the places before mentioned until Trinity munday next as aforesaid shall be utterly void and free for any workman or adventurer to beg the same of the Lords officer provided the said workman or adventurer so begging the same as afores^d^ shall set the said place to work within one month after the begging of the said pitch or pitches and to continue working the same at all times convenient untill he or they shall have wrought the same to effect, otherwise it shall be lawful for the Lords officer to give the same to him or them that will work it to effect and no workman or adventurer so taking up any place shall be allowed to keep no more than two pitches upon either side of his groof and to this we all agree and have subscribed our hands the day and year above written.

John Clark	Thomas Eglefield	Richard Clarke
Samuel House	Richard Coles	Thomas Ridley
John Blackman	Tho^s^ Cutler	John Stanford
John Burge	William Blandon	John Walker
Richard Millard	James Bendle	John Sands
Ambrose Nowles	William Stoakes	George Haskins
William Green jun^r^	Giles Storker	John Parker†

* All of these orders and signatures are written in the same legal handwriting up to the end of this order.

† This order and the signatures are written in the same current handwriting.

103. AT A MINERALL COURT holden at Chewton the 20th day of Novr, 1722, it is Ordered and Agreed upon by Mr John House and his Fellows as followeth.

Whereas there have been Complaint mov'd to us of this Mynrall Grand Jury by Saunder Mackoon that he and his partners have wrought at Shutters Bottom for many Years and have made a Considerable Discovery and being a deep and Wett Country and likewise an hard matter to bring in a Groofe within the Eighteen foott of his first Pitch and desireing our Consideration and judgment hereupon We of this Jury do Order and Agree that it Shall and may be lawfull for the first finder or Elder Pitcher to Strike to any Younger Pitcher any where within his own ground and not be put back to his eighteen foott notwithstanding any former Order to the Contrary and to this we all agree and do Subscribe our hands the day and Year first above written.

John House	John Webb
William Tooey	James Palmer
John Pinkard	Francis Bendell
John Blackman	Richd Witcomb
John Baker	Tho: Clark
James Blandon	John Haskins
James Green	Willm Adams
Stephen Curtis	Jno Hares*
Samuell Smith	

AT A MINERALL COURT holden at Chewton the 29th Day of March in the Year of our Lord 1759, It is ordered & agreed upon with the Consent of this Court by Mr John House and his Fellows as followeth.

104. Whereas the Old Indented Book Containing the Laws and Orders of this Liberty is much defaced and rendered and become through length of time quit unintelligible, We of this Jury do present this Book to be a true Copy thereof and to Contain in a full & perfect manner all the Laws and orders contained in the aforesaid Book relateing to the Liberty of Chewton aforesaid and do present the Same to be in full force from this time and Soforth. To this we all agree and have Subscribed our hands the Day and Year first above written.

John House	Charles Brown
Thomas Clark	John Clark
Joseph Vowles	John Millard
The mark of X Thos Spear	Wm. Millard
William Dudden	James Curtis
William Moare	Robert Anstice
John Bull	Thomas Dallimore
Willm Hares	John Bendel
Thos Ridley	Robert Bull†

AT A MINERALL COURT Holden at Chewton the 29th day of March in the Year of our Lord 1759, it is ordered and agreed upon with the Consent of this Court as followeth.

* This order and the signatures are written in the same legal handwriting.

† This order is written in a legal handwriting, and the signatures are holographs.

Wee of this Jury here present have seriously perus'd the order made by the last Jury for takeing this Book into Court and wee do uphold and Confirm the same, and this we do order and agree.

		William Hares and his fellows.	
	Thoˢ Clark		John Vowles
The mark of X	Thomas Spear		James Dudden
	William Dudden	The mark of X	Richard Nicholas
	Thoˢ Ridley		John Dallimore
	Charles Brown		Joseph Roswell
	John Millard	The mark of X	Wᵐ Class
	Wm. Millard		James Curtis
	John Bendel		Robert Bull
	John Yorkee		John Clark
The mark of X	John Redley		Joseph Vowles*

CHEWTON ROYALTY AND LIBERTY: AT a Mineral Court held there the 25th day of November, 1773, it was then and there ordered and agreed upon by the Mineral Grand Jury as followeth (Vizt).

105. *Concerning Calamy, &c.*—WHEREAS it hath been a custom for time immemorial for the Lords of this Royalty and Liberty to take and recieve one tenth part of all the Lead ore and of all kind of Minerals whatsoever arising and accruing and which have been digged up arisen and landed not only from in and upon the forest of Mendip but also from in and upon the several inclosures in and upon the said Royalty and Liberty. But as the laws customs orders and ordinances contained and comprized in this Book make no mention or take any particular notice of Lapis Calaminaris otherwise called or known by the name of Calamy or Calamine, Magnes Oker or yellow earth (being species or kinds of minerals or Fosils) we presume unknown to our ancestors at the time when the greatest part of the laws and orders were made subscribed and inserted in this Book, which omission appears to us of this Mineral Grand Jury to be the reason why they had not made some particular order or law touching and concerning the same.

Now WE of this Mineral Grand Jury deliberately considering this matter and to prevent (as far as in us do lie) any and all manner of disputes and contentions which may hereafter arise by meanes of and from such an omission, Do HEREBY order and agree that all and every person and persons whomsoever adventuring digging mining and trying for and after Lapis Calaminaris otherwise Calamy or Calamine, Magnes Oker or yellow earth shall be henceforth subject and conformable to all the Mineral laws and orders of the said forest of Mendip relateing to Lead and Lead ore in as full and ample a manner and to all intents and purposes whatsoever, as if the said Minerals or Fosils were of the same species kind or quality whether they adventure work digg mine or try in or upon the said forest of Mendip or in upon or within any of the Said inclosed lands lying and being within the Royalty and Liberty aforesaid: PROVIDED that all such person and persons so mining working and adventuring in the said inclosed lands, have no lease or grant for mining and working such inclosed lands from and under the hand and seal of the Lord or Lords of the fee. AND WE do also further order and agree, that all and every person and persons, adventurer or adventurers, miner or miners, whomsoever, which shall or may

* The signatures are holographs.

hereafter digg, fetch, draw up, or land, or by any other lawful ways or means whatsoever come by or at any Lapis Calaminaris otherwise Calamy or Calamine, Magnes Oker or yellow earth, within the Royalty and Liberty aforesaid shall and will honestly and justly pay or cause to be paid to the Lord or Lords of the fee, or to his or their Agent or Agents, their full tenth part and customary Lott or share (or give good and sufficient security to him or them for the payment thereof) before the goods be removed from the premises, or from the buddles or in default or non-compliance herewith shall forfeit all the said goods to the Lord or proprietor of the Lands, on which the same shall be digged and landed, and be otherwise punished for such offence and offences pursuant to the laws and orders made and provided against delinquents, concerning Lead and Lead ore arising within this Liberty or within the forest of Mendip aforesaid AND shall and will in all kind of disputes and contentions matter and matters thing and things whatsoever touching and concerning pitches, working, keeping of pitches, and repairing them upon the said forest of Mendip digging mining and searching for Lead ore Lapis Calaminaris otherwise Calamy or Calamine Magnes Oker or yellow earth, be it upon the said forest of Mendip or in or upon the inclosed lands within the Royalty and Liberty aforesaid that may hereafter arise whether they be between the Lord and workmen or adventurer or between the Lords tenants and adventurers and their workmen, or between adventurers and adventurers, miners and miners, workmen and workmen, shall be brought before and subject to the Mineral Grand Jury of the Royalty and Liberty aforesaid and be adjudged and determined by them according to the Mineral Laws orders and customs of the forest of Mendip agreeable to that ancient good and equitable law order and custom (namely) that all mineral affairs shall be tryed and determined by a Jury of Mineral men, And to this we do all of us agree and have hereunto set our hands the day and year first above written.*

AT A MINERALL COURT Holden at Chewton the 15th Day of December in the Year of our Lord 1773, it is ordered and agreed upon with the consent of this Court as followeth.

WE of this Jury here present have seriously perused the Order before mentioned dated the 25th of November, 1773, and we do uphold and confirm the same, and this we do order and agree.

John York	Richard Millard
Willm Hares	James Here
William Dudden	W^m X Class
Tho: Redley	Rich^d Nicholls Jun^r
Rich^d X Nicholas	Jn^o X York
Joseph Roswell	Robert Anstice
James Curtis	William York
John Bull	Angelo Gait
Theodore X Payne	Jn^o X Clark
Robert Church	Stephen Yorke
William Hares Jun^r	Fra: X Flower
Fra: X Hares	R. Hippisley
Thomas Pope	Rich^d Clark
Thomas Payne	James Curtis†
James Curtis	

* This order is unsigned. † The signatures are holographs.

CHEWTON ROYALTY & LIBERTY: AT A MINERALL COURT holden at Chewton the 18th day of August in the year of our Lord 1774 it was then ordered and agreed upon with the consent of this Court by Mr John York and his fellows as followeth (that is to say):—

106. WHEREAS at a mineral Court held at Chewton aforesaid the 8th day of July 1671 there was then and there an order made and approved of by the mineral grand jury (namely the 97 order as ranged in this book) in behalf of Thomas Bushell Esqr and Sir Edmund Windham knight and marshell &c. for the encouragemt and more effectual draining and conveying the water from and out of the old deserted lead works at Row pitts and Green Oar within and upon the forest of Mendip by audits, swallets, drains &c. as by the said order will at large appear.

AND WHEREAS Messrs Moses Underwood Jacob Riddle and . . . . . Shapland gentlemen of the city of Bristol being well disposed and very desirous to promote the publick good and presuming they can more effectually convey and drain of the water from and out of the deep and wett works on the said forest of Mendip than has been formerly done HAVE now undertaken and proposeth to bring up a level or levels or subterranean conveyance or conveyances at or near to the said tract or parcel of land called or known by the name of Row Pitts by which means they think it will be highly probable that not only the deep and wett works at Row Pitts aforesaid but likewise those at Small Pitts may be effectually drained and lay so dry as to be worked to the great advantage both of the lord and adventurer BUT WHEREAS this great undertaking will necessarily be attended with an enormous expence to the said undertakers WE of this mineral grand jury with the consent and approbation of the lords officers and several of the most respectable adventurers within the liberty of Chewton aforesaid having seriously and deliberately considered this matter and being very willing and ready to give all the encouragement that lays in our power to an undertaking that may be productive of such publick utility DO HEREBY order direct and allow (as far as our power doth extend, and by our appointment are authorized to do) That the said undertakers Moses Underwood Jacob Riddle and . . . . Shapland their exers admrs and assigns shall have take and receive from all and every adventurer and adventurers miner and miners whatsoever working and mining within the precincts or boundaries of those two several tracts or parcels of land called Row Pitts and Small Pitts mentioned before which may have the use and advantage of any of the levells or level drains or drain made brought up carried on maintained and kept in repair at the sole cost and expence of the said undertakers the same part or share that was paid and allowed to the aforesaid Thomas Bushell and Sir Edmund Windham their executors administrators and assigns for draining and carrying of the water from the works at Row Pitts and Green-oar that is to say one moiety or full half part of all the lead oar that shall or may be drawn raised or landed from out or upon or within the boundaries of the said two tracts of land called Row Pitts and Small Pitts, they the said undertakers Moses Underwood Jacob Riddle and . . . Shapland their executors administratrs and assigns paying and allowing to all and every respective adventurer and adventurers miner or miners one moiety or full half part of all the costs charges and expences that they or any of them may be at on account of digging mining landing drawing and fetching the said lead oar from out of or within the before mentioned premises AND FURTHER WE of this mineral grand jury do order consent and agree that they

the said undertakers their exe^{rs} adm^{rs} and assigns shall have enjoy and be entitled to all and every other profit and profits advantage and advantages that may arise and accrue from the said tracts of land called Row Pitts and Small Pitts, (saving and always excepting to the lord of the soil all his rights priviledges profits duties dues franchises and emoluments whatsoever) and that in as full and ample a manner to all intents and purposes whatsoever as were heretofore granted to the said Thomas Bushell & Sir Edmund Windham according to the true intent and meaning of the aforesaid 97th order for draining and conveying the water from the works at Row Pitts and Green-oar, to which order we of this mineral grand jury do hereby refer to for a fuller and more large explanation of this our order act and deed In witness and confirmation hereof we have hereunto subscribed our names the day and year first above written.

John York
Tho ; Redley
Joseph Rosewell
James Curtis
John Bull
The mark of Theodore X Payne
Robert Church
William Hares Ju^{n}r
Thomas Pope
Tho^{s} Payne
James Curtis
Rithard Millrd

James Here
The mark of W^{m} X Class
The mark of Jn^{o} X York Jun^{r}
Robert Anstice
William York
Angelo Gait
Jn^{o} X Clark
Steph^{n} Yorke
Fra : X Flower
R. Hippisley
Richd. Clark
James Curtis

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

METALLURGY OF LEAD IN MURCIA, SPAIN.

Note sur la Métallurgie du Plomb dans la Province de Murcie, Espagne. *By* P. JANNETTAZ. *Mémoires et Compte Rendu des Travaux de la Société des Ingénieurs Civils de France*, 1900, *series* 5, *vol. i.*, *pages* 705-711.

Most of the lead-mines in Murcia are worked on the tribute system, but though the miners are able to exploit profitably even poor veins of ore, they take no thought of the future of the industry. The washing appliances are simple, but, owing to the cheapness of labour, the stuff is repeatedly sifted, with such good results that attempts to introduce improved apparatus have failed.

In the conditions of sale, no notice is taken of the percentage of zinc, but the price is based on the silver—less ½ ounce—and lead present.

Another special feature of the industry is the employment of a plumbiferous iron silicate met with in abundance. When used in small proportions, its lead-content is not taken into consideration in calculating the charge; the output of lead is therefore apparently increased.

The mineral is roasted in reverberatory furnaces of an average length of 40 to 46 feet (12 to 14 metres), 10 to 13 feet (3 to 4 metres) wide, and provided with at least 7 doors on each side. About 5½ to 6 tons of ore (50 to 55 per cent. and over) are treated in each per day of 24 hours, with a coal-consumption of about 16 to 18 per cent. of the weight of ore. The small works have about 4 of these furnaces, larger ones 8 or 10, and the Puerto de Mazarron works, 22 of larger size.

Formerly, the reducing furnaces were of the natural-draught type invented by Mr. Delgado in 1846; but these have been superseded by blast-furnaces, larger in size, though similar in construction, to the older form, the upper part being mounted on iron pillars, etc., and separate from the bottom, which can thus be easily repaired. The usual height is 13 to 16 feet (4 to 5 metres) with a diameter of 4½ to 6½ feet (1·45 to 2 metres) at the level of the tuyères, of which there are generally 4 to 6. The blast-pressure is low, being only from 4·3 to 5·9 inches (11 to 15 centimetres) of water-gauge.

The charge consists of 400 to 500 parts of roasted ore (60 per cent. of lead) 200 parts of siliceous iron-ore (1 to 2 per cent. of lead); 100 parts of chalk; and 200 to 400 parts of a mixture of scoriæ (1 per cent. and more of lead), soot, and plumbiferous-silicate ore (about 6 per cent. of lead). The lead thus makes about 30 per cent. of the whole charge, and the coke-fuel amounts

to 12 or 15 per cent. The output varies from 5 to 12 tons of lead *per diem* according to the size and working of the furnace. The charge is introduced at intervals of 2 hours, the scoriæ being drawn off continuously, and the lead every 6 hours. Great inconvenience is caused to the workmen by the escape of plumbiferous fumes through the charging-door, which is below the level of the furnace-vault. Every 24 hours, the furnace and crucible are cleaned out and work recommenced. At Puerto de Mazarron, there are 7 water-jacketed Pilz furnaces, 23 feet (7 metres) high, and a large one, 33 feet (10 metres) high, with 16 tuyères, which are about to be doubled by a second set. The same works have also a rectangular American furnace, with 14 tuyères, capable of producing 22 tons of lead per 24 hours. Sea-water is used for the water-jackets, and a rapid circulation is kept up to prevent deposition of saline matters.

At Santa Lucia (Cartagena) and Santa Luisa, Linarès, the work of desilvering Murcian lead is carried on, but the greater part is exported for treatment.

The hilly nature of the mining district facilitated the construction of draught-chimneys, laid on the surface of the hill-slopes, to increase the draught of the furnaces. These chimneys also serve as condensation-chambers, and often attain considerable length, that at Puerto de Mazarron being over 3 miles (5 kilometres) long. In one instance, a condensing-chamber, properly so-called, has been built, provided with a number of sheets of iron hung at right angles to the current of gas. The resulting friction accelerates precipitation, but the iron is liable to corrosion. Owing to the scarcity of water, condensation by the wet method cannot be practised.

The amount of lead lost in the various processes is unknown, owing to the practice, already mentioned, of employing plumbiferous fluxes without reckoning their percentage of lead. C. S.

CALCINING LEAD-ORES.

Neue Bleierz-Röstmethode. *By* C. v. Ernst. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii.*, *pages* 619-620.

A new method of calcining lead-ores has been introduced by Messrs. Huttington and Heberlein. The ore mixed, according to the proportion of sulphur present, with either 6 to 15 per cent. of lime, is heated in a reverberatory furnace to about 700° Cent., and then cooled to about 500° Cent., with the result that from 25 to 35 per cent. of lead sulphate and 2 per cent. of lead oxide are formed without separation of metallic lead, and the loss by volatilization is almost *nil*.

The amount of lead sulphate produced is proportionate to the oxygen in the lime, which, however, is not altered by the reaction, and apparently only serves as a carrier of atmospheric oxygen. The process is repeated until 5 per cent. of unchanged lead sulphide remains, when the product is pulverized, transferred to a converter, and subjected to an air-blast at a pressure of about 1 inch of mercury. After a few seconds, a notable increase of temperature is produced by the oxidation of the lead sulphide and the joint action of the lead sulphate and air. The mass becomes pasty, evolves dense fumes of sulphur dioxide, and finally solidifies, when the operation is finished.

The product contains a mixture of lead oxide with calcium sulphate and lead silicate, all the sulphur being entirely removed even when other

sulphides are present. The final reduction of the metallic lead is effected in a blast-furnace.

The process saves nearly half of the fuel formerly used at the Pertusola, accompanied with diminished losses of lead and silver, and reduced cost of labour. The 9 furnaces in use treat about 38,000 tons of ore *per annum*, and their product is reduced in a single blast-furnace. M. W. B.

A SMELTING PROBLEM.

Mining and Smelting in the State of Durango, Mexico. *By* H. VAN F. FURMAN. *Mines and Minerals* (*Scranton, Pennsylvania*), 1900, *vol. xx., pages* 433-435, *with* 2 *illustrations.*

The ores present a smelting problem which is unique, at least within the experience of the writer. They are extremely basic, containing large quantities of alumina, antimony, arsenic, and but little sulphur. The base bullion resulting from the smelting of these ores contains large percentages of arsenic and antimony, as is shown by the following average analysis of 13 shipments, representing a total of 575,000 pounds:—Lead, 88·6 per cent.; antimony, 4·8 per cent.; and arsenic, 3·6 per cent. In these lots, the antimony varied from 2·7 to 6·7 per cent.; and the arsenic from 2·3 to 5·13 per cent. The silver-content of the bullion varies from 125 to 200 ounces per ton. The average gold-content is 1·4 ounces per ton.

Owing to the extremely base character of the bullion, and the large amount of speiss produced, the ordinary practice of lead-smelting has undergone certain modifications at these works. Operating with the ordinary type of lead blast-furnace, it was found to be practically impossible to keep open the connection between the crucible and the lead-well. Another difficulty arose from the accumulation of speiss-accretions on the hearth of the furnace. To overcome these difficulties, the lead-wells were abandoned, and the crucibles were filled up with brickwork, so as to form a shallow hearth, sloping from the rear towards the front end of the furnace. With this modified blast-furnace, the slag and speiss—there is practically no matte produced—are tapped in the usual way into overflow or settling pots, the slag overflowing into slag-pots of the usual pattern. At intervals of 1 to 4 hours, depending upon the percentages of lead and arsenic in the charge and the working of the furnace, the settling-pot is removed and the furnace is tapped, about 5 inches below the slag tap-hole, for bullion. The bullion is tapped into an ordinary slag-pot, some slag and speiss always accompanying it. The slag and speiss rise to the surface, and when this surface-crust has partially chilled, a bent iron hook is inserted in the centre of the crust. When the crust has solidified, it is lifted off by means of the iron hook. The bullion remaining in the pot, after mixing with a paddle and removing most of the dross, is ladled into moulds. The crusts when cold are broken with sledges, and the slag, which invariably contains shots and sheets of bullion, is separated from the speiss and returned to the blast-furnace. The dross is also returned to the blast-furnace. As the settlers frequently contain bullion when they are changed, just before the furnace is tapped for lead, a hole is broken in the crust and the bullion is poured off into a slag-pot, whence it is ladled into the moulds. The remaining contents of the settler are dumped and, when cold, are broken with hammers, and the rich slag and bullion are sorted from the speiss.

This method proved to be so well adapted to the treatment of these ores that in designing the new plant, which was erected about two years ago, the furnaces were built without lead-wells and with a shallow, sloping hearth. These furnaces have a separate tap for the bullion, 6 inches lower than the slag-tap, located on the side and near the front end of the furnace. When the furnaces are running under normal conditions, they are tapped for bullion every two hours, from 10 to 18 bars being obtained at each tapping. Just before the lead-tap is opened, most of the slag and speiss remaining in the furnace are tapped into the settler. When tapping for bullion, the continued operation of the furnace is not disturbed, it having been found that there is no necessity of stopping or lowering the blast, provided the workmen use ordinary care in tapping. The writer wishes to lay particular stress on this, because after an experience of several months, during which time he was in charge of the smelting-works at Mapimi, he found that the alleged difficulties attending the operation of lead blast-furnaces not provided with an Arent tap were largely imaginary. There are some drawbacks to the method, but with the peculiar ores and under the conditions existing at Mapimi, the practice, as there carried out, gives excellent results. X. Y. Z.

LOSSES IN THE DETERMINATION OF GOLD AND SILVER IN COPPER BULLION; AND A METHOD OF OVERCOMING THEM.

Losses in the Determination of Gold and Silver in Copper Bullion, their Causes, and a Method for Overcoming them. By W. RANDOLPH VAN LIEW. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxix., pages* 469-470 *and* 498-499.

While in charge of the copper analyses of a plant whose output aggregated several hundred thousand pounds of pig-copper daily, the writer's attention was called to the varying results obtained in following the several methods advocated for the determination of gold and silver in copper bullion. This led to an elaborate series of experiments extending over several months, and the final development of a method by which experiments and practical results alike showed a cutting down of the silver loss to under 2 per cent., while the gold loss was lowered to something between *nil* and 0·4 or 0·5 per cent.

Experiments were first conducted with the view of determining the conditions influencing the silver losses. Four sets of six experiments each were operated, in order to determine the influence of the manner of burning the filter-paper. The method adopted, as giving the best results, was to wash every particle of silver chloride to the extreme point of the double filter-paper, cover the cone-shaped mass of silver chloride with 4 to 5 grammes of test-lead, burn the filter-paper in a cold furnace only until the end of the yellow flame, when the scorifiers are removed, and the burning of the remaining carbon takes place outside the furnace, and at such a temperature that no loss of silver by the reduction of silver chloride to metallic silver takes place. The tests by this method showed an average silver loss of 1·7 per cent., as against averages of 2·7 to 3·2 per cent. by the other methods.

But whilst by this method the silver loss was kept under 2 per cent., the gold loss varied from 3·4 to 9·2 per cent., and further experiments were conducted to determine what occasioned this loss of gold and to find out, if possible, a means of overcoming it. The results proved that, so far as a loss of gold was concerned, an excess of sodium-chloride solution exercised no influence; and that, so far from combining with the nitric-acid solution to

cause a solution of the gold, neither nitric oxide (NO), nitrogen peroxide (NO_2), nor nitrogen trioxide (N_2O_3) caused a detectable loss of gold, no matter whether the operation be conducted in hot or cold solutions. But when nitrous acid gas (HNO_2) was combined with a nitric-acid solution there resulted, when the operation was conducted in a hot solution of 82° Cent., a loss of gold varying in four different trials from 29 to 52 per cent.; and on the other hand, when these trials were conducted in all respects under similar conditions, excepting that the temperature was maintained at 15° Cent., the loss varied from 0·85 to 2 per cent. The extreme loss in the case of the hot solution was intensified by the conditions of the experiments, but the influence of heat in effecting a solution of the gold when nitrous acid (HNO_2) is present in the nitric acid (HNO_3) solution clearly indicated the necessity of keeping the solution as cold as possible during the dissolving of the copper.

The method finally evolved by the writer to overcome this solution of the gold, and at the same time, to keep the silver loss down to the lowest point, was as follows: The copper weighted in duplicate of 1 assay-ton samples each was treated with 350 cubic centimetres of very cold water, and 100 cubic centimetres of nitric acid (HNO_3) (specific gravity 1·42), the beakers were set in a cool place, and the temperature kept down to 15° or 16° Cent. After 18 or 20 hours, enough acid is added to take in solution the rest of the copper. At the end of 24 or 26 hours, the solution of the copper is complete. Instead of removing the lower oxides of nitrogen by boiling or heat, compressed air was used. In 20 or 30 minutes, these oxides are entirely removed. By this method of solution, heat is applied at no stage of the process, and the loss of gold is minimized. Experiment having justified the procedure, there was added to the cold solution of copper nitrate (Cu_2NO_3) an excess of 2 to 4 cubic centimetres of normal sodium-chloride solution, besides that necessary to precipitate all the silver present. The next morning, the silver chloride was filtered off, the entire contents of the filter washed to the point of the filter-paper and the mass of silver chloride covered with 4 to 6 grammes of test-lead; the drained papers were then placed in 2½ inches scorifiers, whose bottoms contained about 1 gramme of test-lead, then dried, and burned in a furnace below a temperature of incipient redness. The filter-papers not being allowed to burn to complete ash in the furnace, but, removed at the end of the yellow flame of the papers, have to burn the carbon of the charred paper outside the furnace, this slow combustion taking place at a temperature too low to cause any loss of silver in being reduced from silver chloride. In 20 minutes, the papers ashed, when no more lead was added, but 3 to 4 grammes of litharge and 3 to 4 grammes of borax glass. The copper all having been washed away in transferring the silver chloride to the point of the filter, no scorification is necessary to get rid of any impurities. The resulting buttons of lead weigh from 4 to 5 grammes and are cupelled at a temperature giving heavy litharge feathers, and allowed to blick at the temperature they are run, there being no difficulty as to every trace of lead going off when no other impurities are present. When run this way, duplicates easily check, on the silver, within 0·2 and 0·3 ounce. The time of operation is 48 hours instead of 24 by the usual method.

This method was tested side by side with the standard 24 hours method on the daily samples of converter-copper; the period of comparison was three weeks; covering that time there was, of course, no difference in the silver, but there was an average gain of 6·75 per cent. of gold in favour of the 48 hours method. X. Y. Z.

COST OF SMELTING SILVER-LEAD ORES.

Notes on Lead Smelting and Gold and Silver Refining: Cost of Smelting Silver-lead Ores. *By* MALVERN W. ILES. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix., pages* 258-259.

After alluding to several general factors that are comparatively obvious, the writer states that the size of the furnace, the general shape, arrangement of parts, and convenience in operation, are potent factors in lessening the cost. The general healthfulness of the furnaces, where the ore is introduced and where the molten products issue, bears directly upon the cost per ton. The western lead-smelters have quite recently recognized the fact that, in order to burn carbon fast, oxygen should be supplied fast. Smelting has been greatly cheapened by using higher volumes and pressures of air. When the tonnage was increased by the use of better blowing machinery, and the leaders in smelting introduced blowing-engines like those used in the smelting of iron-ores, this marked the greatest revolution in the history of this industry. For many years, the use of blowing-engines was a consuming thought to the writer, and the progressive spirit of the management of the Globe smelter, at Denver, enabled this concept to lead up to a great success. In order to show the strides which have been made during the past 12 years, the following figures are given of the results obtained at one of the large lead-smelters in the west:—

AVERAGE COST PER TON FOR SMELTING.

Year.	Cost. Dollars.	Year.	Cost. Dollars.	Year.	Cost. Dollars.
1887	4·644	1891	4·170	1895	2·786
1888	4·530	1892	4·096	1896	2·750
1889	4·480	1893	3·375	1897	2·520
1890	4·374	1894	3·029	1898	2·260

Even where the smelting has been lowered to 11s. 6d. (2¾ dollars) per ton. there is far too much hand-labour yet employed, and it is believed that by employing a better system for the handling of the material to and from the blast-furnaces, improvements will result. More steam, more compressed air and electrical appliances could be used without excessive cost. The chief cost of smelting is the coke, which is rather poor.

Where iron-fluxes are expensive, it is very necessary to make as siliceous a slag as possible without interfering too greatly with the tonnage. To state the positive amount is difficult, as it depends on the zinc, alumina, etc., contained in the slag. But the best points will usually be found near the figure of 31 to 34 per cent. of silica. In order to do the cheapest smelting, the percentage of lime in the slag should be constantly experimented on. Whenever the slag runs high in lead, continue adding more lime until the slag runs low in lead. Sometimes, however, the lead in the slag is due to the use of insufficient fuel, too cold water-jackets, and leaky water-jackets. The writer sums up as follows:—(1) Use as little fuel as possible; (2) use as much air as possible; (3) use as little flux as possible, particularly iron-flux, where expensive; (4) pass all the slag through a reverberatory slag-settler; (5) filter all the fume through cloth; and (6) remove the fume from the blast-furnaces by fans, and see that the vacuum pressure is at least ¼ ounce per square inch. X. Y. Z.

THE REDUCTION OF GOLD-ORES IN THE CRIPPLE CREEK DISTRICT, COLORADO.

The Cripple Creek Mining District, Colorado. By DR. G. F. HAZLEHURST. *The Engineering and Mining Journal (New York), 1900, vol. lxx., pages 454-455 and 545-546, with a map and 2 illustrations.*

The writer describes the geology, mines, machinery, etc., of the Cripple Creek district in Colorado. The processes employed at the works of the Colorado Ore-reduction Company, south of Elkton, are as follow:—In the sampling department, the ore is passed through a Blake crusher 9 inches by 15 inches, then through Davis rolls 14 inches by 27 inches, then into a Vezin cut-out till it is reduced to 200 pounds. It is then put through another set of Davis rolls 12 inches by 12 inches, and crushed to a No. 6 mesh; then cut to 12 pounds by hand, dried in an Engelbach drier, and the pulp put into four samples.

In the crushing department, the ore is crushed to ½ inch mesh, dried in a cylindrical drier built after the White-Howell pattern, and carried by a belt to a system of fine crushing-rolls consisting of 3 sets of Davis rolls 14 inches by 27 inches, with 6 sets of revolving screens which reduce the pulp to a 24 mesh. These screens are provided with a knocker of new design, which increases the capacity by one-fourth and doubles the life of the screen-cloth. The rolls are provided with devices whereby the roll-shells are kept true without any trimming whatever, thus getting the full wear out of all the material in the shell. From the rolls, the ore is carried by a screw-conveyor into bins, then trammed by hand to a Ropp roaster, and thence by a chain-conveyor provided with a water-jacketted trough to storage-bins. From these bins the roasted ore is trammed to the two different processes which are employed as the character of the ore requires.

The potassium-cyanide process as here employed may first be described. In the leaching room there are 4 tanks of 50 tons capacity each, 2 of 65 tons each, and 2 of 150 tons each. The pulps remain in the cyanide solution until the gold has been dissolved. The solution is drawn from the tanks through a filter-bottom fixed in each; the gold in solution is washed out of the pulp by water, after which the tailings are sluiced over a system of riffles, thus effecting another extraction from the tailings. All the solution is then passed through boxes which contain zinc shavings, the contact of the gold-bearing solution and the zinc causing a precipitation of gold in the form of a double cyanide of zinc and gold. This precipitate is known as zinc-slimes, and these are treated by sulphuric acid, converting the zinc into zinc sulphate which is washed out by hot water, while the residue is melted in an ordinary wind-furnace and cast into gold bars. The solution is afterwards standardized by the addition of more potassium cyanide, and used as before.

The chlorination-process is described as follows:—In the barrel-room are 3 barrels, 2 holding 10 tons each and the other one 5 tons. They are lined with sheet-lead and provided with filter-bottoms of hardwood and lead. Into them is poured the roasted pulp with certain quantities of bleaching-powder, sulphuric acid, and water. A cover is screwed over the charging-hole, and the barrel revolved on its trunnions. The chlorine produced attacks the gold, and in the presence of water forms trichloride of gold. This solution is drawn off from the barrel, sufficient water being added to wash the pulp; it is then allowed to settle for several hours in a lead-lined tank, whence it is pumped into other tanks, in which the gold is precipitated by the passage of hydrogen sulphide. This precipitated sulphide of gold is allowed to

settle till the barrel solution is practically clear. The tank is then tapped about 4 inches above the bottom, and the clear solution is drawn off and passed though a filter-press, so that any gold-slimes which may be in suspension can be saved. These gold sulphides are washed into the filter-press, worked by compressed air, then taken out and roasted in a muffle furnace until they are free from sulphur. They are afterwards melted in a wind-furnace, and cast into gold bars.

Both steam and electricity are used for power purposes in this mill, and oil is in use for fuel in the roasting-furnace. X. Y. Z.

THE SOLUBILITY OF GOLD-SILVER ALLOYS IN CYANIDE-OF-POTASSIUM SOLUTIONS.

Notes on the Solubility of Gold-Silver Alloys in Cyanide-of-Potassium Solutions. **By** DONALD CLARK. *Proceedings of the Royal Society of Victoria*, **1898**, *new series, vol. xi., pages* 147-151.

Experiments were undertaken in order to determine the solubility of gold and silver alloys in potassium-cyanide solutions. Since pure gold never occurs in nature, and alloys seldom or never contain less than 60 per cent. of gold, a series of alloys containing from 60 to 95 per cent. of gold were prepared for solution. The metallic strips measured 1 inch in length, $\frac{1}{4}$ inch in width, and $\frac{1}{300}$ inch in thickness. A 0·25 per cent. solution of potassium cyanide was employed, and care was taken to ensure that the gold had a constant supply of cyanide. It was intended to have dissolved each of the strips completely, but it was found that, after 597 hours' contact, the gold had commenced to separate out in fine flakes, and that several of the strips were eaten through, so it was decided to assay the undissolved alloy in order to find out whether its composition remained unaltered. Strips cut from the same alloys were subjected to the same solvent, circulating and stationary. The action in the latter case, as might be expected, was slower. Next, the same series of alloys were used to test the solubility of gold in chlorine solutions. The results of the experiment (which the author tabulates very elaborately) show that an alloy containing 95 per cent. of gold is dissolved more readily than pure gold or than alloys having a greater percentage of silver; that the alloys are not dissolved regularly and evenly, but that in some cases the action of the solvent is slower at first and more rapid afterwards; that those alloys approaching the formula AuAg, are more evenly dissolved than those differing widely from that formula; and that the circulating solution dissolves more gold in the same time than the fixed solutions.

In the case of the saturated chlorine-solution, the action was exceedingly rapid as compared with the cyanide, but even after 90 hours' contact only from 50 to 85 per cent. of the strips was dissolved. In the case of the 0·1 per cent. solution of chlorine, the action was so slow that, in 304 hours, only from 4·85 to 15·89 per cent. of the metals was dissolved.

Since it requires 130 parts of potassium cyanide and 106·5 of chlorine to dissolve gold and keep it in solution, then a 0·2 per cent. solution of chlorine should be almost equivalent to 0·25 per cent. of potassium cyanide. On testing certain roasted ores by both processes, it was found that a 0·25 per cent. solution of potassium cyanide and a 0·2 per cent. solution of chlorine dissolved almost equal quantities of gold in 72 hours, the slight difference being in favour of the chlorine. With badly roasted ores, and with ores con-

taining large quantities of arseniates, it is not possible either with one solution or the other to dissolve a high proportion of the gold present; but with ores which have been properly roasted, and in which the gold is fine, it will be found that an ordinary solution of potassium cyanide will act as well as chlorine, and with the additional advantage that the silver alloyed with the gold will be dissolved, and may be recovered also. It would appear that the most effective potassium-cyanide solution (proved by Mr. Maclaurin to be a 0·25 per cent.) is not so rapid in action as the chlorine solution usually worked with in practice; but it must be borne in mind that the chlorine solution (0·4 per cent.) is twice as strong as the potassium-cyanide solutions generally used. X. Y. Z.

OXYGEN IN THE CYANIDE PROCESS.

Oxygen in the Cyanide Process. *By* W. JONES. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix.*, *page* 404.

When the writer went to South Africa as metallurgist for the Rand Central Ore-reduction Company, he found that it was the practice in treating slimes to pump air into the solution-vats. Without this air the gold could not be satisfactorily dissolved, whilst with it there was no trouble in dissolving practically all the gold. Experimental work showed that, with slimes which had been stored for some time and contained organic matter or other oxidizable substances such as sulphur, arsenic, etc., it was only possible to dissolve a small percentage of the gold that they contained, whilst after supplying oxygen, the cyanide dissolved all the gold very rapidly. This led to the practice of forcing air to the bottom of the vats and allowing it to bubble up through the solution; and subsequently, this method of introducing the air was modified and a less expensive method adopted, the slimes being pumped from the bottom of the vat and thrown in at the top while at the same time air was drawn into the suction-pipe. After explaining the theory, the writer concludes that the use of air is a modification of the cyanide process to be used under certain conditions, or where the ore contains oxidizable matter. In cases where the ore does not contain such matter, the solution generally carries enough air to answer all purposes, any excess being of no value. X. Y. Z.

NOTES ON THE AUREX SLUICE.

Notes on the Aurex Sluice. *By* T. M. CHATARD *and* CABELL WHITEHEAD. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxix.*, *pages* 138-140.

For some time past, the writers have been experimenting with a view to utilizing the well-known effect of an electric current in increasing the rapidity of the solvent effect of potassium-cyanide solutions upon gold in its ores. Much work has already been done in this direction by others, and processes have been devised. All these processes, however, are open to two objections:—(1) They are not continuous in operation, the ore having to be worked in batches; and (2) large amounts of electric current must be used, of which only an infinitesimal portion does effective work: this is due to the large resistances that have to be overcome by the current in seeking out the precious metals to be dissolved. The writers endeavoured to minimize this expenditure of electrical energy by bringing the precious metals to the current by gravity. The apparatus devised for this purpose is called the "aurex sluice."

It is a trough, upon the floor of which are laid curved wooden blocks closely butting together, and upon these are placed amalgamated copper-plates curved to fit the blocks. The plates are slightly smaller than the blocks, to admit of easy removal and replacement; they therefore do not touch each other, the electric connection being made by means of mercury poured into the interspaces. This method also ensures connexion with the negative electrodes, the copper-plates being the cathodes of the cell. Above each plate is placed its anode, which is a leaden plate curved approximately like the cathode, but so differing that, when the sluice is given its proper grade, the lower edge of the anode is nearer the cathode than the upper one. As this lower edge dips into the valley formed by the curves of the two adjacent cathodes, the effect of this contraction is to produce a slight increase of pressure in the flow of the solution, just sufficient to prevent the heavier ore-particles from settling in the valley. This increase of pressure can be regulated both by the grade of the sluice and by causing the lower edge of the anode to approach or to recede from the cathode, and should be just sufficient to keep the ore in motion without causing any scouring action upon the cathodes; in this way, ore of any of the usual mill-grades of fineness can be handled. Another advantage of this form of anode is that the current of electricity, which always takes the path of least resistance, exerts its greatest force at the lower end of the anode, just where every particle of the ore is brought into most intimate contact with the nascent cyanogen liberated by the action of the current.

The test-plant consists of 20 feet of such a sluice, in three lengths, disposed as three sides of a square, the fourth side being taken up by an elevator, which lifts the pulp from the tail of the last sluice to the head of the first, thus securing any desired number of feet of linear flow. In the contracted space available, this elevator, though otherwise disadvantageous, is necessary, since an important element in a successful electrolytic extraction of metals from ores is, evidently, the length of time during which the ore is exposed to the action of the electric current. During the passage of the pulp through the sluice, the solution is continually extracting values from the ore, but at the same time is continually depositing its contents of precious metal upon the amalgamated cathodes. Owing to the form of these plates an excess of mercury can be used upon them without danger of loss in tailings, and this, with the action of the electric current and of the potassium cyanide, gives an always bright and soft amalgamating surface, upon which any coarse gold present in the ore is caught and retained, while the fine float-gold is dissolved and precipitated.

When making a test run, the elevator is started and the current turned on. The ore, mixed with the potassium-cyanide solution, is then charged into the boot of the elevator, and the circulation thus established is kept up for a certain definite time. From 25 to 50 pounds of ore and 100 pounds of potassium-cyanide solution make a full charge for such a sluice, and give a pulp of proper thinness. At the end of the circulation period, the stream is turned into the tail tank, the sluice washed free from ore and the tailings drained, washed, dried, and sampled. The percentage of extraction is given by the assay of the tailings, while the amount of deposition of gold and silver upon the cathodes is shown by the assay of the solution at the beginning and end of a run. Frequently, several trials must be made before the best conditions for a successful extraction can be determined. Sometimes the need of finer grinding is thus indicated; at

other times this is of no avail, since the values remaining in the tailings are in such form as, however finely divided, are not acted upon by the cyanide, even with the aid of electricity; again, at times, the need of some form of special treatment is shown, such as roasting, either plain or chloridizing. X. Y. Z.

SEPARATING PLATINIFEROUS GOLD.

Ueber die Scheidung von Platinhaltigem Golde. *By* DR. E. PŘIWOZNIK. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii.*, *pages* 356-358.

The method adopted at the Austrian Royal Testing Station when the platinum is present otherwise than in the state of an alloy, is as follows:—

The metal is digested with pure nitric acid (specific gravity 1·199) so long as silver continues to dissolve, a portion of the platinum also passing into solution. After decanting the liquid, the residue is washed and treated with an *aqua regia* consisting of 100 cubic centimetres of concentrated hydrochloric acid, 43 cubic centimetres of concentrated nitric acid, and 143 cubic centimetres of water, which will readily dissolve gold and copper in the cold, but leaves platinum untouched. As soon as the evolution of gas-bubbles and red nitrous fumes has ceased, the liquid is removed, the residue being washed and shaken up with ammonia to dissolve any adherent silver chloride. Fresh acid is then added, and the treatment repeated until all the gold and silver have been extracted, leaving the platinum behind in the pure state.

The silver solutions are united and treated in the usual manner for the recovery of this metal. The gold solutions are heated with repeated additions of hydrochloric acid until the nitric acid has been driven off and gold chloride crystallizes out. These are re-dissolved in water, and the whole liquid is treated with ammonium chloride to throw down, as a double chloride, the small proportion of platinum present. The residual solution is then precipitated with ferrous sulphate, and the gold fused with borax and potassium nitrate.

When the metals are in the condition of an alloy, it is preferable to form a zinc or lead alloy previous to the acid treatment. Zinc is the better of the two, owing to the ready precipitation of plumbic chloride along with the silver. The alloy (3 or 4 parts of zinc to 1 part of gold alloy) is granulated, and treated with concentrated sulphuric acid to dissolve the zinc and leave the granules in a porous or pulverulent condition. These are afterwards treated in the manner already described. C. S.

DETECTION OF QUICKSILVER IN MERCURIAL GREY COPPER-ORE CONTAINING TRISULPHIDE OF ARSENIC AND OF ANTIMONY.

Die Ermittlung des Quecksilbers in Schwefelantimon- und Schwefelarsenhaltigen Quecksilberfahlerzen mittels der Golddeckelprobe. *By* F. JANDA. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii.*, *pages* 205-208.

In determining the amount of quicksilver in ores containing trisulphides of arsenic and of antimony by means of the Eschka gold-test, iron-scale or filings and zinc-white are usually mixed with the ore to form the charge. The deposit of quicksilver obtained is generally overlaid with oxide of antimony or arsenic acid, for which these two fluxes are useless. The Eschka test, which consists mainly in heating the ore in a crucible with a cover of

gold, is more accurate and rapid than the usual unsatisfactory methods of distillation and electrolysis. To prove its efficacy, experiments were made on samples of grey copper-ores from Hungary, Tyrol, Bosnia and elsewhere, containing 3·5 to 9 per cent. of sulphide of antimony, 0·6 to 5 per cent. of arsenic trisulphide, and a little bismuth. Sodium carbonate and manganese-ore were used as fluxes, as well as iron-filings and white zinc, and gave interesting results. The charge was placed in a porcelain crucible with a gold cover, and heated over a Berzelius alcohol-lamp.

If grey antimony be roasted in the open air, a certain quantity escapes as an oxide with the sulphurous acid; the white powder which remains, oxide of antimony (Sb_2O_3), if heated in the open air is converted into antimonic tetroxide. If the arsenical pyrites be roasted in the open air, arsenic acid and sulphurous acid are formed. The arsenic trioxide (As_2O_3), a white powder, volatilizes at 200° Cent.; and a grey metallic powder remains, which oxidizes easily in the air at a high temperature. As the object of the tests was to solidify the arsenic and antimonic tetroxides, calcined sodium carbonate was used as a basic flux, and the iron-pyrites was oxidized with powdered manganese-ore, as an oxidizing-flux.

Binoxide of manganese, if gently heated, loses about one quarter of its oxygen, and decomposes into black manganic oxide; at a strong heat, it loses a third of its oxygen, and forms manganic protoxide. This oxidizing-flux is more suited to rich pyritic ores than iron-filings and zinc, especially in detecting traces of quicksilver. Powdered and calcined sodium carbonate retains the volatile arsenic and antimonic tetroxides, and sets free the carbon dioxide. Iron-filings, which contain varying quantities of oxides, tend when repeatedly heated to become oxidized and to increase in weight. That iron-scale acts on the products of distillation was proved by heating wood in a porcelain crucible; when covered with filings, the gold cover and interior of the crucible were quite clean; when the wood was burnt without the filings, the internal surfaces were covered with a tarry deposit and a certain amount of sulphide of iron. The uppermost layer of the charge should be zinc-white, thoroughly dry, and of the best quality, otherwise the quicksilver may be discoloured. This strong flux decomposes the mercuric sulphide. Oxygen is set free by the reaction, and the metallic sulphide desulphurated. If no zinc be used, the amalgam will contain sulphide of mercury. The zinc also acts in the same way as the iron-filings in retaining the products of combustion, as proved by similar experiments.

When the samples of ore were heated with these fluxes over the Berzelius lamp, the temperature inside the crucible did not reach glowing heat, namely, 525° Cent. No fusion of the products took place, as the soda prevented the arsenic and antimonic sulphides from caking. When powdered ore alone formed the charge, the temperature was 320° Cent.; with the addition of the iron-filings it rose to 370° Cent., showing that the latter, being a good conductor of heat, increased the temperature. At 310° Cent., the mercuric sulphide was completely volatilized, and the products showed no trace of quicksilver. The heat generated was not high enough to reduce the zinc oxide and the arsenic and antimonic sulphides to a metallic state, and so produce an amalgam.

With oxidized waste-products from the mines, which contain chiefly metallic or oxidized quicksilver, the manganese-ore may be omitted, and only sodium carbonate, iron-filings, and zinc used. If too much manganese-flux be added the quantity of quicksilver will be diminished, and mercuric

oxide formed. But when substances containing foreign bodies, such as splinters, hair, etc., are tested for quicksilver, it cannot be recovered in a pure state unless manganese-ore and soda be added. Ten minutes was found long enough for testing from ½ to 10 grammes of powdered ore, but this depends on its porosity and richness in pyrites. The products left in the crucible did not cake, and were easily removed.

The quicksilver condensed on the gold cover of the crucible was pure, and showed no traces of arsenic or antimony. To remove it, the gold cover, after wiping, was placed over the lamp and heated slightly till the quicksilver was volatilized, and afterwards brought to a red heat for a few minutes. Whatever kind of lamp be used, the gold cover should never be too rapidly heated, otherwise the boiling quicksilver would loosen the gold and form an amalgam with it, thus wasting both metals, and also injuring the surface of the cover.

A table is given in the original paper, showing the value of the above fluxes for treating grey copper-ore, when combined as follows:—From 1 to 10 grammes of finely powdered ore, 6 to 9 grammes of iron-filings, 1 to 2 grammes of manganese-ore, and 2 to 3 grammes of carbonate of soda, the quantities varying with the composition of the ore. Over this are spread a thin layer of iron-filings and a thick layer of white zinc. If the ore is already oxidized, from ½ to 10 grammes must be previously mixed with 6 to 9 grammes of filings, and 2 to 5 grammes of sodium carbonate, and then treated as above. Three series of tests were made on ore, oxidized waste-products, and other mixtures. They were treated with iron-filings and white zinc alone, with these combined with sodium carbonate, and lastly with the addition of manganese-ore. The first set gave very unsatisfactory results, the surface of quicksilver being impure and broken. When the four fluxes were used, the percentage of mercury varied from 2½ to 4¾ per cent., and pure quicksilver was obtained. The best result for these particular ores was furnished with soda, filings and zinc. The quicksilver was very pure, and the percentage varied from 0·58 with Tyrolese ore, to 60 with waste from the Bosnian mines, and 34 with the products from Hungarian mines. The mean percentage in the ore from these mines was 4·76. B.D.

POWER-TRANSMISSION BY GAS AND ELECTRICITY.

Power Transmission by Gas and Electricity: The Efficiencies of Steam and Gas Engines for Generating Electric Power. By ALTON D. ADAMS. *Mines and Minerals* (*Scranton, Pennsylvania*), 1900, *vol. xx., pages* 447-448.

The author points out that the development of gas-engines possesses great interest as promising the most economical transmission-system over long distances. The energy developed as mechanical motion in their cylinders bears a much larger ratio to the total energy from coal consumed than is the case in steam-cylinders, besides which the value of the coke and other products of gas-manufacture is greater than the value of the coal from which they are obtained. Even when fuel-gas, obtained from slack anthracite, is used, less than 1¼ pounds of this coal will furnish sufficient gas for each horse-power per hour, so that the gas-engine increases the chance of financial success of electric transmission of power by cutting down the fuel-item at the commencement.

It is further pointed out that the gas itself can be transmitted over long distances more cheaply than electricity can. And the author's contention is

that the most economical system of transmitting power over long distances is the following: The gas is made at, or in the immediate vicinity of, the coal-mine, pipe-lines are laid to the receiving-station, the gas is pumped through this main, and utilized by gas-engines at the receiving-station. Taking as an illustrative example the transmission of 10,000 horsepower over 150 miles, the writer computes that where an electrical transmission may develop an efficiency of 62 per cent., the efficiency of the gas-transmission system will be 82 per cent. These figures for efficiency refer to the final delivery of energy in the form of direct electric current from each system. If the transmitted energy is to be used for heating, the computation is that the electric system will deliver to the consumer about 13 per cent., and the pipe-line system about 90 per cent. of the units of heat in the total gas consumed. X. Y.Z.

THE SAULT SAINTE-MARIE POWER-CANALS.

The Sault Power Canal. *By* WALDON FAWCETT. *Scientific American*, 1900, *vol. lxxxii., pages* 328-329, *with* 5 *illustrations.*

At the present time, 1,500 men are engaged in the excavation of this canal, an undertaking which is believed to be the greatest hydraulic development ever attempted in the United States. The sister cities of Sault Sainte-Marie, Michigan, and Sault Sainte-Marie, Ontario, it may be explained, are situated on either side of the St. Mary's River, which connects Lakes Huron and Superior, and through which passes the bulk of the enormous commerce of the great lakes. The river, at a point opposite the cities, takes a tremendous drop by means of rapids, and it was to obviate this obstacle to navigation that the governments of Canada and the United States constructed a number of canal-locks, one of which is the largest in the world. All the claims which have been made for the possibilities of development at Niagara Falls apply with equal if not greater force to the Sault Sainte-Marie. A water-power canal, ½ mile long, is already in operation on the Canadian side, and a canal, 1½ miles long, is under construction on the American side. It will supply a row of mills upon its banks more than 1 mile in length, and will give each a fall of water of 18 feet and an ample quantity. In short, the whole scheme is designed to turn the two twin cities into a vast water-mill, with Lake Superior as a mill-pond, and there is in contemplation a scheme whereby the generation of electricity will enable factories of various kinds to secure power over an area fully 15 miles in diameter. Within the past year, the Consolidated Lake Superior Company, with a capital of £4,200,000 (20,000,000 dollars) was formed to absorb the interest of all the original companies engaged in the development of the two industrial centres.

Measured by the ordinary rules of hydraulics, the actual energy to be developed by the canal on the American side will amount to fully 60,000 horsepower. The power-house within which this power will be transformed into electrical energy will be 1,400 feet long, 100 feet wide, and will rise 75 feet above water-level. Its construction will require 250,000 linear feet of piles, 100,000 linear feet of 12 inches logs, 1,080,000 cubic feet of concrete, 3,000 tons of structural steel, and 270,000 cubic feet of stone masonry. The installation will comprise 320 turbines, and 80 dynamos.

Lake Superior has an area of about 30,000 square miles, and its mean outflow through the rapids at the Sault Sainte-Marie is about 90,000 cubic feet per second all the year round. The mean elevation of the lake is 601 feet,

and the elevation of St. Mary's river below the rapids 582 feet, giving a vertical fall of 19 feet. Of this power, the undertaking described aims to convert 60,000 horsepower into electrical energy. X. Y. Z.

POTTERY-MANUFACTURE AT THE IDRIAN QUICKSILVER-MINES.

Die moderne Hafnerei auf der k. k. Quecksilberhütte in Idria. By KARL MITTER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii.*, *pages* 571-572.

Since the quicksilver-mines in Idria were first worked, clay-vessels for handling the mineral have always been required, and therefore the manufacture of pottery has from the beginning been an important industry at these mines. Formerly, it was carried on by a contractor, who supplied the mines, and afterwards furnished vessels for the production of mercuric sulphide or vermilion, at a fixed price. In the course of the present century, the pottery-manufacture passed through various hands, and in 1876 was taken over by the mining-director, who formed it into a separate branch, materials for which are supplied by the mines.

The potteries have lately been reorganized and considerably enlarged. The clay-bowls which from time immemorial have been used to carry the ore from the mines to the furnaces have now been replaced by enamelled pots. Fire-clay linings for the furnaces, and many articles required in the daily work of the mines, which were formerly purchased elsewhere at a high price, are now supplied from these potteries on the spot. The covers of the charging-furnaces used to be brought from Bohemia, and were frequently damaged in transit; the house-stoves came from Laibach, but both are now turned out in workmanlike fashion at the potteries. Of the pipes, fire-bricks, covers, pots, kilns, etc., produced, the average output is now about 36,000 articles a year, a quantity far larger than the old potteries could turn out, because they were so badly situated that the clay could never be dried out of doors. Since 1893, a spacious building well suited for the purpose has been allotted to them. Here black clay from a neighbouring quarry, fire-clay, and chamotte or broken fire-bricks and furnace-linings are worked. They are dried and ground in a mill to fine powder, litharge being used as a glaze, and quartz-powder is mixed with the wet clay. For fire-resisting articles, a mixture of half chamotte and half fire-clay is employed. Tiles for the stoves, pipes, pots, casks, and other things required for the quicksilver are made of black clay and quartz-powder, and for articles exposed to great heat very slaty clay is selected.

The potteries now contain workshops, drying-rooms, a heating-chamber with two furnaces, the grinding-mill and kneading-machine, an engine-room, a store-room for the powdered clay, and other chambers, all connected by small tram-lines. Twice a year every place is cleaned out thoroughly, to collect the waste quicksilver. The materials for making the pottery are prepared in a kneading-machine, which has proved very useful. It is driven by steam, and delivers the stuff ready for use, at a cost of about 1¼d. per cubic foot. Thus a very great economy is effected over the former hand-labour. It is found also that, whereas formerly with manual labour, the clay was never thoroughly kneaded, the process is now so completely effected by means of the machine, that the work itself is more durable, and a better quality of pottery is produced. B. D.

THE MINING LAWS OF RUSSIA.

Place -mining in the Southern Ourals. By CHARLES TAPPAN. *The Engineering and Mining Journal* (*New York*), 1900, *vol. lxx., pages* 35-36 *a d* 67-68.

As the Russian Government is granting mining rights to foreigners, and is very willing to have foreign capital invested within its boundaries, and as the Russian mining law has not within the writer's knowledge been translated and published in English, the following summary may be of interest to mining engineers.

Anyone can own mines, who has secured a miner's right; the right is for life, and non-residents may acquire it. The preliminaries for a foreigner are complicated, and include a certificate from the police or the law-courts of the applicant's native country that he is not insolvent, and the Russian Consul nearest the place of residence must certify that this certificate is in proper form.

The location of mining-claims is simple. Digging a small hole, planting one post at the beginning-point, and filing with the police of the sub-district a paper describing the claim constitute the first step. This is called a *zaiafky*, literally an entry, the same word that is used in the agricultural-land business of the United States. Zaiafkies are either for veins or placers. One person may enter a vein-claim adjoining his own entry for placer; but he cannot have the beginning-points of two veins or two placers closer to each other than 5 versts (about 3⅓ miles), though adjoining claims may be acquired by purchase. It is the custom for the wife and relatives of a mine-owner to take out mining rights, and thus the law against entering adjoining claims is practically inoperative.

A placer-claim is limited in area to 104 dessiatinas (say 280 acres), and the greatest length must not exceed 5 versts (say 3⅓ miles); a vein-claim cannot exceed 1 square verst. The beginning-point on a placer, that is the point marked in the ground by post and pit, must be the lowest point. The entire claim must lie on ground higher than this point, and the placer cannot include any ground, except such as has a natural drainage towards the beginning-point. If the beginning-point is set within 2 versts of the head of a stream or gulch, it will be curtailed that much, as one is not allowed to go over the divide and down another gulch. No one can file a zaiafky with a beginning-point within the limits that may be covered by a previous zaiafky. For example, if a zaiafky begins just below the junction of three streams, the land for 5 versts up each stream is closed to all prospectors. The owner may then select his ground all in one gulch, or he may have a forked claim running up all the gulches. The official land-surveyor is paid by the Government, but it is customary to give him 40 or 50 roubles "for tea," and also 10 to 15 roubles to the army officer, who is always detailed to watch that the land-surveyor is not bribed.

The filing of the zaiafky gives the right to explore the ground by shafts or otherwise, but not to take away any gold. All the gold that may be found must be thrown back into the shafts (this law, of course, is never observed), and the shafts must be filled up. The real working of the claim cannot begin, until the official survey has been approved by the head engineer of the district. If it is desired to work the claim immediately after the zaiafky is filed, a Government surveyor will be sent at the owner's expense, and the official measurement will be made "at once," which in Russia means a week, or a month, or more. In this way, work may commence within 2 or 3 months after the zaiafky is filed. Usually, the official survey is not made sooner than two years after filing the zaiafky.

Before beginning the work of getting gold, a notice must be sent to the head mining-engineer for the district stating that the work is about to be started. With this notice must be enclosed an undertaking in which either the owner himself—or the superintendent, but generally the foreman—agrees to be personally responsible for any accidents that may happen. If anyone is killed or injured, the person signing the undertaking is liable to imprisonment.

The number of puds of sand washed and the weight of gold recovered must be entered in a book every day. The books for this record are official books obtained from the Mining Bureau. The book must be posted and signed by the superintendent and the foreman every day, and must be always ready for inspection by the head mining-engineer or his deputies. The gold recovered must also be kept on hand at the mine, and its weight must agree exactly with the total recorded. Any error in the keeping of this book is punished by a fine of £2 to £20. No one is allowed to sell gold, or to use it in trade; and all gold recovered must be deposited with the Mining Bureau. The gold is weighed, melted, and assayed, just as it is in the United States assay-offices, but the Russian Government desires the presence of the mine-owner or his representative during the melting, etc. The gold is paid for at the rate of about 90¾ per cent. of the coinage-value of the metal. This is the direct tax on production. There is also a tax on the land, which is fixed at the time of approval of the official survey. This tax depends on the acreage of crown lands covered by the claim, and ranges from nothing to 100 roubles per annum. When part of a claim is upon village-community lands, the village authorities demand an annual tax. Within recent years, this has been successfully resisted in the courts, in cases where the mine-owner could show that his workings were not injuring the producing qualities of the community-lands, but wherever the workings destroy grain-fields or pastures, proper recompense must be made.

There are many technicalities and legal formalities to be observed. For example, nothing can be done without a power of attorney properly executed before a notary public. Everyone about a mine, except the common labourers, must have a power of attorney from the owner. Copies, duly stamped and attested by the notary must be filed with the head mining-engineer of the district. As the notaries live almost 100 miles apart, the expense for powers of attorney is quite a considerable item, especially as none of them is good for longer than one year. The law also provides for filing several monthly statements. One of these is a list of workmen, giving names, ages, passport-numbers, etc. The foremen must have licenses, which are obtained after an examination before the head mining-engineer. Mines must be timbered according to the methods taught in the Ural Mining School, and judging from results, these methods are very poor. There are numerous fines which may be incurred, should the head mining-engineer come to the mine, and find that some slight technicality has been disregarded.

Personal inspection of the plant by the head mining-engineer is necessary before using steam. Whenever a boiler is erected, a diagram of the mine showing the position of the workings, and a plan of the boiler with the buildings near it must be sent to the head mining-engineer with petitions and powers of attorney. He is allowed two months in which to make his inspection. Personal acquaintance with this high official may secure an early examination, but as a general rule nearly 2 months of idleness follows the erection of every boiler. It is customary to present the head mining-engineer with 100 roubles and his travelling expenses.

The law as to the use of water is quite simple. If there is a stream within the surveyed limits of the claim, it can be freely used for gold-washing. If not, then the owner and the officers of the village community must agree on a water-rent, usually very light. Conflicting water-rights are unknown, there being no irrigation.

The official land-surveyor marks the boundaries of every claim by posts and pits at each corner, and by plough-furrows along each line. As the posts are always stolen for fuel, the pits and furrows are the only things to depend upon. Fortunately, they are easily traceable even after 15 or 20 years. It may be well to state that no piece of wood should ever be left unguarded, or it will surely be stolen. If a timbered mine is left without a watchman, the natives will risk their lives to rob it of every stick.

X. Y. Z.

MINING LEGISLATION IN CHINA.

Note sur la Législation des Mines en Chine. *By* — LECLÈRE. *Annales des Mines*, 1900, *series* 9, *vol. xviii.*, *pages* 249-260.

In 1898 and 1899, the author journeyed about in the provinces of Yun-nan, Sze-chuan, Kwei-chao, and Kwang-si: these include what are probably the most important mining areas of Southern China. Indeed the acquisition of mineral deposits appears to have been the principal object aimed at, in the conquest of these territories by the Chinese about the middle of the seventeenth century.

The inhabitants of the Celestial Empire, being bereft of any exact knowledge as regards mineral deposits, and having no notion of underground topography, consider all that lies below the surface as the realm of the infernal genii or earth-dragons. Temples dedicated to the latter have been built on many mineral outcrops, and thus it is that coal is often found in places called He Long Tan (Birthplace of the Black Dragon). The miners believe, if any of the customary superstitious observances are neglected; if the workings are pushed forward too energetically; nay, if a mandarin or an European sets foot in the mine, that the ore-body or other mineral mass will be spirited away by the earth-dragons who control it. The Emperor is looked upon as the hereditary depositary of the power of the dragons, but his exercise of this power is involved in a whole network of traditions and ceremonial rites.

The right of working as a miner is hereditary, and constitutes the inalienable patrimony of certain families. No restriction has ever existed as to the area within which such families may carry on prospecting and exploration-work: the right holds good all over the Empire and for all mineral deposits that may be discovered in the future, as well as for those that have been temporarily abandoned. The result is, of course, that there are in China in the eye of the law no unworked or abandoned deposits. The European capitalist who attempts to start mining in the Middle Kingdom may consequently expect to find his path barred on every hand by vested rights (of prior discovery and prior occupation) difficult to foresee in their full extent, but duly registered in family archives. Just as there are hereditary miners and hereditary agriculturists, so too in China there are hereditary metallurgists, and if the head of one of these families hires men to assist him, these are regarded by a convenient fiction as kinsmen.

The mandarins, then, do not altogether lie when they tell Europeans that

the mines belong to the people or in some cases to the Emperor, and that the sole interest of the Government therein is to secure to a certain number of families the means of earning their living. Yet a district mandarin may stop the local working of mines on grounds of public policy, and he practically dictates the conditions of sale of the minerals.

A duty patented miner may dig a pit or drive an adit wherever he pleases, provided that he keeps at least 2 *changs* (say 50 feet) away from any excavation previously made by another miner. Each man has a right to all the mineral lying within 1 *chang* of the wall of his excavation. Opencast workings are rare, for want of the necessary capital to lay bare a sufficient area. Once started, the underground galleries are carried on in any direction that appears most advantageous to the miner. The main gallery is generally well timbered, but low (about 4 feet high as a rule), and dips in every imaginable way in the endeavour to follow up the mineral deposit. Lateral galleries branch off in what are considered the most favourable directions. Want of air, inflows of water, falls of rock, and sometimes blowers of gas are the only recognized obstacles to the pushing forward of the workings. The number of workpeople varies according to the richness of the deposit: the average wage is from 2 to 3 *taels* (say 7 to 10 shillings) *per mensem*, together with rations of rice provided by the mine-owners. The latter never remain long in possession of capital: they are practically throttled by the exactions of the mandarins, and the extortionate prices charged by tradesmen who supply them with necessaries and lend them funds. Generally the miner borrows capital at an usurious rate of interest (paying sometimes as much as 100 per cent.) from a loan-syndicate duly authorized by the local mandarin. The loan is repayable in kind: that is, in ore extracted from the mine, and, as there is no guarantee attached to it or security given, supposing that the year prove unprofitable the borrower betakes himself elsewhere to seek his fortune while the lenders may "whistle for their money." They are not allowed to set foot in the mine, or to interfere under any pretext in the management thereof. As a whole, the condition of the mine-owner and his average gains are hardly superior to those of the workmen whom he employs. Thus it is that a man who engages in mining, even if he only assumes the technical management of operations, is looked upon by the Chinese as one of the working-class. Less than ever will he secure their respect if he happens to be a foreigner.

The miner in extending his underground workings pays scant regard to the rights of the surface-owner. No royalty is due to the latter so long as the workings do not emerge above ground. Nor is compensation paid for damage to fields or houses, unless the landowner happens to be a very influential person. In the case of those deposits (coal being among them) which are reckoned by the mandarins as comparatively unimportant, permission to start an excavation has to be obtained from the surface-owner. He generally takes care to claim what is really equivalent to a royalty, in the shape of one tenth of the mass of raw mineral got from any excavation started in his ground. The miner may freely dispose of the remaining nine-tenths, save the obligation which local custom may lay upon him to provide neighbouring villages with the mineral, and save the payment of a yearly tax to the local mandarin. When, however, a deposit is considered of sufficient importance (*e.g.* copper-ores, gold, silver, lead, sulphur) to warrant the claim of pre-emption advanced by the Government, or to give rise to the formation of a privileged loan-syndicate, direct sale of the minerals to the

public is forbidden under severe penalties. The entire output must be placed in the hands of agents of the mandarins or of the syndicate: they undertake the treatment of the ores and the sale thereof. The quantities delivered are credited to the mine-owner, in accordance with an official tariff, fixed yearly in the case of copper and the precious metals by the Imperial Government, and in the case of other minerals by a board of merchants and mine-owners whose chairman is the mandarin entrusted with the superintendence of mining industry. Generally the tariff appears to favour the miner, but the buyer "gets his own back," by taking advantage of the want of fixity in weights and measures, and using scales which secure him an "unearned increment" of 12 to 15 per cent.

The mine-owners are extremely jealous of each other, and they are not above the suspicion of concealing their actual output, so as partly to evade their obligations to the loan-syndicates. When two mines, having been pushed forward by guesswork in the same deposit, cut one into the other, the matter is usually settled by arbitration. Only in the event of persistent disagreement are such cases brought before the local mandarin, as this always proves to be a costly method of settling them. Every mine-owner is liable for such accidents to persons as may happen within his workings (or even for those which occur outside them, when such accidents can be held to result from his mining operations). Chinese law and custom take no cognizance of such possibilities as fortuitous occurrences, or contributory negligence on the part of the victims. Opportunities of blackmailing thus arise, and may be especially turned to account in the case of foreigners.

In conclusion the part played by the Imperial Government in the mineral industry of China has no technical bearing: it is confined to fiscal pressure applied to whatever syndicate is in possession of the monopoly of sale. Although the taxes or duties levied by the syndicates are very complex, and variable from district to district, the total charges which weigh upon the mines are remarkably uniform throughout China: they amount to 25 or 30 per cent. of the value of the total output. The people recognize the superiority of European methods, and would be willing enough to secure the advantages manifestly derived from them, but do not think that there is anything to be learnt. They believe that Western progress is a mere application of the principles of which China has been the depositary since the remotest antiquity, and that they need neither European help nor advice, in order to produce from the most complicated machinery which we can put before them the most magnificent results. L. L. B.

II.—REPORT OF THE CORRESPONDING SOCIETIES COMMITTEE OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, BRADFORD, 1900.*

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The following Corresponding Societies nominated as delegates to represent them at the Bradford meeting:—The Institution of Mining Engineers, Prof. Henry Louis; Midland Institute of Mining, Civil and Mechanical Engineers, John Gerrard; North of England Institute of Mining and Mechanical Engineers, M. Walton Brown; Mining Institute of Scotland, James Barrowman.

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First Meeting of the Conference, Bradford, September 6th, 1900.

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Copyright.

Mr. M. Walton Brown brought forward the question of copyright. Lord Monkswell had introduced into Parliament a Bill dealing with the subject, and, so far as scientific societies were concerned, the Bill ignored some important points. In the first place, there was no provision that a society should have any copyright in the publication of its own *Transactions*, though he believed societies might obtain copyright if they paid their contributors. He had offered to give evidence before the Committee considering this Bill, but the Committee replied that they accepted his evidence, and did not think it necessary to examine him. Then the Bill proposed to make the insertion of abstracts of foreign scientific papers a breach of copyright; an innovation that would weigh heavily on several scientific societies which made a special point of publishing abstracts.

Mr. Eli Sowerbutts thought that this was one of the most important matters that had ever been discussed at a conference. Copyright questions were extremely involved, and difficult to understand; but there could be no doubt of the injustice of the present state of things, and that it would be confirmed by the Bill then before Parliament. The expense of printing papers was by no means a slight one.

Prof. Henry Louis pointed out that the British Association disclaimed copyright for itself. It was, however, a matter of vital importance to each society represented at that conference.

After some remarks from the Rev. J. O. Bevan and the Chairman, the following resolution, moved by Mr. M. Walton Brown and seconded by Mr. Sowerbutts, was carried unanimously:—

That the matter of the proposed Copyright Bill be referred, through the Committee of Recommendations, to the General Committee, so far as it affects (1) the copyright of scientific societies in their *Transactions*; and (2) the publication of abstracts of scientific papers; and that they be requested to take such action as will protect scientific societies.†

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† The resolution was by an accident not sent to the Committee of Recommendations, but it has been arranged that it shall be brought before the Council for consideration.

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Second Meeting of the Conference, September 11th, 1900.

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DEW-PONDS. By Professor L. C. MIALL, F.R.S.

I lately undertook a new edition (the 83rd or 84th) of White's book on *The Natural History and Antiquities of Selborne*, and found it necessary to consider the account of the Hampshire dew-ponds which is to be found in Letter XXIX. to Barrington. "We have many such little round ponds in this district, and one in particular on our sheep-down 300 feet above my house, which, though never above 3 feet deep in the middle, and not more than 30 feet in diameter, and containing perhaps not more than 200 or 300 hogsheads of water, yet is never known to fail, though it affords drink for 300 or 400 sheep, and for at least 20 head of large cattle beside." This account, of which I quote one sentence only, led me to inquire a little into this curious subject by correspondence, by reference to the rather scanty literature which already exists, and by personal visits. My inquiries are, I must admit, very imperfect, but they may be the means of inducing people whose opportunities are better than mine to collect fuller information.

White's account of the dew-ponds of Hampshire is largely confirmed by more recent observation. A good description of such ponds is to be found in a prize essay on *Water Supply*, by the Rev. J. C. Clutterbuck. He says that the tops of chalk hills, where no surface-water or springs can furnish a supply, are often chosen as the sites of dew-ponds. "They are constructed by persons of experience and skill. At the spot selected an excavation is made in the surface of the chalk, either round or rectangular, from 30 to 40 feet or more in diameter, from 4 to 6 feet deep. The bottom, of a basin shape, is covered in portions with clay carefully tempered,* mixed with a considerable quantity of lime to prevent the working of the earthworms.† As the portions are finished they are protected from the action of the sun and atmosphere by a covering of straw. When the whole bottom of the pond is so covered with an efficient and impermeable coating or puddle a layer of broken chalk is placed upon it to prevent its injury by cattle or other means. Their cost varies from £30 to £50. When all is finished water is introduced by artificial means. If there is a fall of snow, this is collected and piled up in the pond as the readiest and least expensive method of accomplishing the object. . . Ponds so constructed and filled have been known for periods of 20 or 30 years never to become dry. The summer of 1864 was a notable exception."

Dew-ponds are often dug on the very ridge of a down, or else by choice on the northern slope, which is the inland slope in most of the south-eastern counties. It is generally held that moist winds throw down their water most abundantly just beyond the summit of the first range of hills which they meet. In the case of the downs of Hampshire and Sussex, the inland slope has the further advantage of being sheltered from the sun and all the warmer winds, so that it is the fitter for the condensation of water-vapour.

Mr. Clutterbuck believes that dew-ponds are "not easily accounted for by recognized physical causes." It is plain that the water which collects on the

* Chalk-puddle is occasionally used instead, but is believed to be less efficient and less durable.

† It may be doubted whether the purpose of the lime is to prevent the working of earthworms, which cannot live beneath a pond. It is an old practice to spread wet clay with lime the in belief that it prevents slipping.

summit of a chalk-down is not drawn from springs, for the saturation-level is hundreds of feet below. Nor is it due in any important measure to surface-drainage. A small collecting area is furnished by the margin of the pond, but this rarely equals the water-surface. A dew-pond may occupy the summit of the ridge so precisely that there can be no collecting ground worth speaking of.

Hales' view (quoted by White) that more than twice as much dew is deposited upon water as upon an equal surface of moist earth cannot be accepted as it stands. He does not take into account circumstances which may greatly affect the rate of cooling, and consequently the amount of condensation, such as the depth of the water. It may often be observed, for instance, that when a copious dew has been deposited upon the seats of an open boat none is to be seen on the bottom. Contact with a large body of insufficiently cooled water (as of a deep lake) has kept the bottom of the boat at a temperature above the dew-point.

Water is so bad a conductor of heat that some difficulty may be found in understanding how a pond can cool sufficiently during a summer night to act as an efficient condenser. But though water conducts heat very badly, every surface layer, as it cools by radiation, becomes denser, and sinks. Continual replacement of the surface layer by convection-currents may thus cool down the water as effectually as if the heat were freely conducted away. A shallow pond on a hill-top may in the course of a few hours become cold enough to act as an efficient condenser.

Water-vapour, liquid-water, and ice are all good absorbents of dark heat-rays; it may be inferred that they are good radiators of dark heat-rays. This perhaps does not admit of experimental proof. The radiation from water in a pond is complicated by so many circumstances, such as the absorption of heat by the water-vapour which the pond gives off, and the sinking of the water as it cools, that no determination by direct methods is possible.

There is a good deal of testimony to the effect that a dew-pond prospers best with a depth of about 4 feet. If it is deeper it shrinks to such depth as will cool down during a short summer night, namely, about 4 feet; if it is much shallower it dries up altogether in a drought. This account, though probable in itself, needs to be scrutinised farther. I know as yet of no facts to the contrary, and several in its favour.

Dew-ponds abound in Sussex and Hampshire, and are not uncommon on the chalk hills of Berkshire and Wiltshire. But on the chalk hills of Hertfordshire, Bedfordshire, Lincolnshire and Yorkshire few or none are to be found. This may be connected with the distance from the sea in a north-east-to-south-west line. The south-west winds, which bring the chief part of our atmospheric moisture, can reach the South Downs almost direct from the sea, while they can only reach the chalk hills of the Midlands and the North of England after traversing a great extent of country and crossing many ranges of hills.

The few that have been mentioned to me as occurring in the Midland counties all turned out on inquiry to depend obviously on surface drainage, usually from a hollow in a neighbouring hard road. It is thus with the meres of Derbyshire, which appear, from such information as I have been able to procure, to be always fed from adjacent collecting grounds. If anyone can furnish an unexceptionable example of a true dew-pond on a chalk-down, or other hill, which is distant a hundred or even fifty miles from the south coast, the news would be welcome.

Those who believe that dew-ponds in all cases owe their existence to rain-fall alone (and among these was that eminent meteorologist, the late Mr. G. J.

Symons, F.R.S.) hold that, owing to elevation, the temperature of the water in such ponds is very nearly coincident with the dew-point, so that evaporation and condensation balance each other. Whether such a temperature of the water is regularly maintained day and night throughout a season of drought cannot, I believe, be established by existing thermometric observations. I doubt whether it can be established by general reasoning. Before we can accept the view that dew-ponds are replenished by rain alone, we must refute or explain two facts, both of which are supported by strong testimony:

1. That dew-drops do not dry up when the low-level ponds of the same district are evaporated. Not only do the dew-ponds replace in some way the loss due to evaporation, but they supply large flocks of sheep. If it is contended that during summer droughts the hill-tops are regularly visited by local clouds which are precipitated as rain, the frequency and substantial yield of such clouds need to be better established that at present.

2. That dew-ponds cannot in the first instance be filled by rain (see Mr. Clutterbuck's prize essay). This statement, if it can stand inquiry, seems to be decisive against the sufficiency of rain-fall.

On the other hand, the restriction of dew-ponds to an area quickly and directly reached by south-west winds blowing from the sea, supports, it would seem, the view that what we call dew-ponds are really rain-ponds. Moisture-laden winds favour cloud-formation and rain, while we have no reason to suppose that they favour dew-formation, but rather the contrary.

Mr. Clement Reid, F.R.S., of the Geological Survey, sums up his wide experience of dew-ponds in these words:—

"The conditions that are required for a permanent dew-pond do not seem generally to be understood, failure or success appearing to be the result of chance rather than of any clear comprehension of the principle on which the dew-pond acts. On comparing, at the end of a long drought, the dried-up ponds with those that still contain water, we find that, other things being equal, the best dew-pond has the following characteristics:"

"It is sheltered on the south-west side by an overhanging tree, often only a stunted ivy-covered thorn or oak, or by a bush of holly. Or else the hollow is sufficiently deep for the south bank to cut off much of the sun. The depth or shallowness of the water does not appear to make so great a difference as would be expected."

"The open downs, even in the middle of summer, receive much heavier dews than would be expected, or than are met with on the lowlands. Thick sea-mists often cling to their tops for several hours after sunrise, while the plains below are already dry and sunny. It is only by noticing the large amount of moisture intercepted and dripping from the over-hanging boughs as the sea-mist drifts slowly past that one can realise how prolific a source this must be. The amount condensed in this way might be tested by a rain-gauge of wide aperture."

"When one of these ponds is examined in the middle of a hot summer day it would appear that the few inches of water in it could only last a week. But in the early morning or towards evening, or whenever a sea-mist drifts in, there is a continuous drip from the smooth leaves of the overhanging tree. There appears also to be a considerable amount of condensation on the surface of the water itself, though roads adjoining may be quite dry and dusty. In fact, whenever dew is on the grass, the dew-pond is receiving moisture; and this moisture, owing to the shade of the overhanging tree, is partly preserved throughout the day; so that sheep or cattle may drink daily from a small shallow pond which receives no rain, and yet the pond be not exhausted unless the nights are exceptionally dry."

We now want observations by the thermometer. We should be glad to know the temperature of the water of the pond at various depths, as taken hourly through a summer night; the temperature of the surface of the ground (free from grass) a few feet away from the pond; the temperature of the air at various small heights above the hill-top, as well as in a neighbouring valley; and also the relative humidity of the air as determined by wet and dry bulb thermometers. If a small party would make such observations during a few clear, still nights in hot summer weather some blanks in our knowledge would be filled up at once. We should be glad to know how the level of a dew-pond varies during a spell of sultry weather. Observations on the clouds and mists of the summits of the downs are also much to be desired. Day observations would have their use too, and should not be omitted.

Is it too much to ask that residents in the south-eastern counties will investigate these matters for us? A party of a dozen meteorologists who would choose a time of settled hot weather, and give a week to the inquiry, would throw much light upon a question of considerable scientific and practical importance.

While so many data are wanting, it would be unwise to express a confident opinion as to the relative importance of rain and dew in the supply of water to the ponds of the chalk downs. No scientific man will willingly decide any question on indirect evidence if direct evidence can be got.

In making inquiries about dew-ponds I have been helped by many friends and correspondents, among others by Mr. W. Whitaker, F.R.S., Mr. Clement Reid, F.R.S., Mr. John Hopkinson, Mr. T. W. Shore, Mr. F. J. Bennet, Mr. John Brigg, M.P., Professor G. S. Brady, F.R.S., and the Rev. Henry Green.

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The CHAIRMAN (Mr. W. Whitaker) remarked that they would all unite in thanking Prof. Miall for bringing before them the subject of dew-ponds in so complete a form. He should like to have a little further information as to the habit of sprinkling with lime with the object of keeping out earth-worms. He wished also to know on what grounds Prof. Miall said that evaporation from the surface of dew-ponds was slight. His own impression was that evaporation would be somewhat rapid. Prof. Miall had spoken of the limited area within which dew-ponds existed. It was singular that this limited area was one of low rainfall. Dew-ponds were numerous in Berkshire, where they were made in the way described by Prof. Miall. While the Hertfordshire chalk was largely covered by clay with flints, the Berkshire chalk was not.

Mr. CLEMENT REID said that the question of the water-supply in dew-ponds was, like many other questions of water-supply, much mixed up with curious ancient superstitious observances analogous to the use of the divining rod. He did not think that dew-ponds were formed in anything like the scientific manner pretended by their makers. He had been working during the last few years in a country where dew-ponds were particularly abundant, and there had been several successive years of severe drought. Nearly all the more recently made dew-ponds were dried up, but a number of the older ones had not dried up. He did not think that the older ponds were better made than the newer ones, but that a process leading to the survival of the fittest was always going on. When a dew-pond dried up a new one became necessary. The farmers were constantly making new ones, and sometimes, by accident, they got a satisfactory site. It was an unfortunate thing that they were almost entirely without meteorological observations on the high ground, where dew-ponds abounded, our rainfall stations being almost invariably at a low level. As to the question of dew or mist he did not feel qualified to speak. He wondered whether it was possible that the film of scum constantly seen on the surface of dew-ponds had any influence in protecting the water from evaporation. Dew-ponds, being entirely isolated from running water, were very important from a biological point of view. They could watch the population of a pond becoming more numerous and varied, and note how the higher animals and plants took the place of the lower which first appeared. Dew-ponds and other isolated ponds would give much valuable information as to the rate of dispersal of the aquatic fauna and flora of a district, and their observation with this object was a matter which might well be recommended to all local scientific societies.

Mr. VAUGHAN CORNISH said that in Berkshire the dew-ponds were frequently in open situations and not under trees. He would bring the matter before the notice of the Dorsetshire Field Club, and he hoped they might be able to make some systematic observations on dew-ponds.

Mr. JOHN HOPKINSON noticed that Prof. Miall held that the margin of the pond had very little effect in increasing the amount of rain collected, but he believed that, as a rule, the area of the margin was at least equal to that of the surface of the pond. There was thus twice the area for rainfall that would be given if the water-covered surface alone were reckoned. It was difficult to form an idea as to how water was contributed to these ponds by dew, as dew would require a surface cooler than the air on which to condense, whilst the water in the pond would usually cool more slowly than the air above it. The water being also warmer than the surface of the ground surrounding it, dew would not so readily condense on it. He believed that observations had been made, but he was not aware that anyone had actually seen the dew accumulating on the side of a pond and trickling down into it. The margin

had certainly very little, if any, effect as regards the amount of dew received. A distinction must be drawn between dew and mist: the latter would probably increase the amount of water in a pond. As to the level of these ponds, he believed that it varied considerably from time to time. Where there were trees overhanging the pond, there would be a considerable deposition of dew, but he thought that the majority of these ponds were not surrounded by trees. As to evaporation from the ponds, mist was to be seen at times rising from their surface. He believed that the average rainfall where dew-ponds were situated was between 25 and 30 inches per annum. But there were scarcely any rain-gauges on the high ground where dew-ponds existed, and there was probably more rain on the hills than in the valleys. He did not know of any dew-ponds in Hertfordshire, though there was a considerable area around Royston and Hitchin where there was bare chalk. He thought the subject extremely interesting, and one which might be profitably studied by the local societies. Among other results their investigations might some day enable farmers to fix upon the best possible sites for their dew-ponds, and so prevent the waste of a considerable amount of money.

Mr. CLEMENT REID remarked that the ponds which had stood the severe drought had generally trees on their margin.

Mr. J. BROWN said that in order to form an accurate estimate of what was going on it would be necessary to consider the amount of water consumed by the animals drinking at the pond. There were no dew-ponds in Ireland.

The CHAIRMAN remarked that dew-ponds were only made in a country like that of the higher chalk districts, where the rocks were absolutely dry.

Mr. W. GRAY said that there was a great deal of superstition about water, and some of the account of dew-ponds which never failed, etc., probably owed much to that source. There were wells in Ireland the water of which it was said would not boil, and the people never used it for cooking, because they thought that it would be useless for that purpose. This notion evidently arose from the fact that the water from a deep-seated source is of the same temperature in summer and winter, and the inference of some people was that it would be of no use to attempt to change the temperature artificially.

Mr. W. M. WATTS said that with regard to the mixture of lime with clay in the sides of a dew-pond, he did not think that it was necessary to make them impervious; but lime was frequently mixed with sandy material to prevent it from slipping in the slope of a reservoir embankment. With regard to the amount of dew, that could hardly exceed 1½ inches per annum.

Mr. JAMES BARROWMAN was not aware that there were any dew-ponds in Scotland. One point to be considered was whether the superficial area of the pond had anything to do with its success.

Mr. HOPKINSON thought that it was of considerable importance in the construction of these ponds that in the summer the receiving area was usually more than double the evaporating area.

Mr. G. P. HUGHES said that dew-ponds were unknown in his district. It occurred to him that they might prove useful in the future both in Australia and in South Africa—dry countries where the dews were very heavy.

The Rev. E. P. KNUBLEY remarked that Wiltshire was a country of dew-ponds. He suggested that all the delegates should be supplied with a list of questions, which they might attempt to answer by the date of the next meeting.

Prof. H. LOUIS remarked that the exact composition of the water in these dew-ponds was one of the essential points to be examined.

Prof. POTTER said that in Warwickshire there were many ponds which it was almost impossible to suppose could be fed by surface drainage. In Suffolk, there were a great number of small ponds which formed the water-supply of villages, and were covered over and not supplied by rain. In the south of Portugal, there was a well-defined wet season of short duration and a prolonged summer, in which no rain fell at all. In that country there were many rock-pools, and from the scarcity of the rainfall and the excessive heat, it was impossible to suppose that these pools had been fed entirely by the rain.

Prof. MIALL replied, and expressed the hope that the Corresponding Societies would take up the subject and furnish additional information on dew-ponds.

The CHAIRMAN requested the delegates to bring the subject before their societies.

Mr. VAUGHAN CORNISH remarked that he would see what could be done in Hampshire and Berkshire to induce people to take the matter up.

The Rev. E. P. KNUBLEY added that he would try to interest some residents in Sussex.

SECTION C.

Mr. MONCKTON, representing Section C, drew attention to the labours of two Committees who wished to obtain the co-operation of the Corresponding Societies in their work, the Geological Photographs Committee and the Erratic Blocks Committee. As regards geological photographs, the county of Yorkshire and the scientific societies of Yorkshire were pre-eminently first in the work up to the present time. The number of geological photographs in the British Association's collection was 2,655, the number received during the past year being 309. In this list, he did not include a certain number of duplicates and lantern slides. It was so obvious that the taking of geological photographs was a work which could be most usefully done by members of the societies that he need say nothing more on that head.

Then the Committee for the Investigation of the Erratic Blocks of the British Isles wished for the active co-operation of the members of the Corresponding Societies. Individual workers could greatly aid this investigation, but the most effective assistance would be given by the organisation of local boulder committees. He would therefore suggest that the delegates should impress their respective societies with the importance of organising local boulder committees, and of communicating the results attained to the Erratic Blocks Committee. It might be useful to add that the Secretary of the Geological Photographs Committee is Prof. W. W. Watts, and the Secretary of the Erratic Blocks Committee Prof. P. F. Kendall.

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COMMITTEES APPOINTED BY THE GENERAL COMMITTEE AT THE BRADFORD MEETING IN SEPTEMBER, 1900.

1.—RECEIVING GRANTS OF MONEY.

Subject for Investigation or Purpose.	Members of the Committee.	Grants.
		£ s. d.
Seismological observations	*Chairman.*—Prof. J W. Judd. *Secretary.*—Prof. J. Milne. Lord Kelvin, Prof. T. G. Bonney, Mr. V. C. Boys, Prof. G. H. Darwin, Mr. Horace Darwin, Major L. Darwin, Prof. J. A. Ewing, Prof. C. G. Knott, Prof. R. Meldola, Mr. R. D. Oldham, Prof J. Perry, Mr. W. E. Plummer, Prof. J. H. Poynting, Mr. Clement Reid, Mr. Nel on Richardson, and Prof. H. H. Turner.	75 0 0
To investigate the erratic blocks of the British Isles, and to take measures for their preservation. [£5. in hand.]	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Prof. P. F. Kendall. Prof. T. G. Bonney, Mr. C. E. De Rance, Prof. W. J. Sollas, Mr. R. H. Tiddeman, Rev. S. N. Harrison, Mr. J. Horne, Mr Dugald Bell, Mr. F. M. Burton, Mr. J. Lomas, Mr. A. R. Dwerryhouse, Mr. J. W. Stather, Mr. W. T. Tucker, and Mr. F. W. Harmer.	—
The collection, preservation and systematic registration of photographs of geological interest. [£10 in hand]	*Chairman.*—Prof. J. Geikie. *Secretary.*—Prof. W. W. Watts. Prof. T. G. Bonney, Dr. T. Anderson, Mr. A. S. Reid, Mr. E. J. Garwood, Mr. W. Gray, Mr. H. B Woodward, Mr. R. Kidston, Mr. J. J. H. Teall, Mr. J. G. Goodchild, Mr. H. Coates, Mr. C. V. Crook, Mr. G. Bingley, and Mr. R Welch.	—
To study life-zones in the British Carboniferous rocks.	*Chairman.*—Mr. J. E. Marr. *Secretary.*—Dr. Wheelton Hind. Mr. F. A. Bather, Mr. G. C. Crick, Mr. A. H. Foord, Mr. H. Fox, Mr. E. J. Garwood, Dr. G J Hinde, Prof. P. F. Kendall, Mr. J. W. Kirkby, Mr. R. Kidston, Mr. G. W. Lamplugh, Prof. G. A. Lebour, Mr. B. N. Peach, Mr. A. Strahan, and Dr. H. Woodward.	20 0 0
The movements of underground waters of north-west Yorkshire.	*Chairman.*—Prof. W. W. Watts. *Secretary.*—Captain A. R. Dwerryhouse. Prof. A. Smithells, Rev. E. Jones, Mr. Walter Morrison, Mr. G. Bray, Mr. W. Lower Carter, Mr. W. Fairley, Prof. P. F. Kendall, and Mr. J. E. Marr.	50 0 0
Terrestrial surface-waves and wave-like surfaces.	*Chairman.*—Dr. Scott Keltie. *Secretary.*—Colonel F. Bailey. Mr. Vaughan Cornish, Mr. A. R. Hunt, and Mr. W. H. Wheeler.	5 0 0
To investigate the resistance of road vehicles to traction.	*Chairman.*—Sir Alexander Binnie. *Secretary.*—Prof. H S. Hele Shaw. Mr. W. W. Beaumont, Sir D. Salomons, Mr. J Brown, Mr H. Maclaren, Mr. Aveling, Mr. W. H. Wheeler, and Prof. T. Hudson Beare.	75 0 0
Corresponding Societies Committee for the preparation of their report.	*Chairman.*—Mr W Whitaker. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Prof R. Meldola, Dr. J G. Garson, Sir John Evans, Mr. J. Hopkinson, Prof. T. G. Bonney, Sir Cuthbert E. Peek, Mr. Horace T. Brown, Rev. J. O. Bevan, Prof. W. W. Watts, Rev. T. R. R. Stebbing, Mr. C. H. Read, and Mr. F. W. Rudler.	15 0 0
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2.—Not Receiving Grants of Money.

Subject for Investigation or Purpose.	Members of the Committee.
Comparing and reducing magnetic observations.	*Chairman.*—Prof. W. G. Adams. *Secretary.*—Dr. C. Chree. Lord Kelvin, Prof. G. H. Darwin, Prof. G. Chrystal, Prof. A. Schuster, Captain E. W. Creak, the Astronomer Royal, Mr. William Ellis, and Prof. A. W. Rucker.
The rate of increase of underground temperature downwards in various localities of dry land and under water.	*Chairman and Secretary.*—Prof. J. D. Everett. Lord Kelvin, Sir Archibald Geikie, Mr. James Glaisher, Prof. Edward Hull, Dr. C. Le Neve Foster, Prof. A. S. Herschel, Prof. G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, Prof. Michie Smith, and Prof. H. L. Callendar.
The nature of alloys.	*Chairman and Secretary.*—Mr. F. H. Neville. Mr. C. T. Heycock and Mr. E. H. Griffiths.
That Mr. Alfred Harker be requested to prepare a report on the constitution of igneous and metamorphic rocks.	—
To consider the best methods for the registration of all type specimens of fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary*—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, Prof. H. G. Seeley, Mr. H. Woods, and Rev. J. F. Blake.
The collection, preservation and systematic registration of Canadian photographs of geological interest.	*Chairman.*—Prof. A. P. Coleman. *Secretary*—Mr. Parks. Prof. A. B. Willmott, Prof. F. D Adams, Mr. J. B. Tyrrell, and Prof. W. W. Watts.
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THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1900–1901.

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204, George Street, Glasgow. R. Barnett Johnstone and R. McLean	192	None	2s. 6d.	Annals, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C. ..	Rev. W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	252	None	£1 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863..	Belfast Nat. F. C. .	Museum, College Square. William Gray and Dr. W. D. Donnan	330	5s.	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831..	Berwicksh. Nat. Club ..	Rev. G. Gunn, M.A., Stichill, Kelso, N.B.	400	10s. 6d.	7s. 6d.	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	Birm. & Mid. Inst. Sci. Soc.	H. C. Adams, Birmingham and Midland Institute, Paradise Street, Birmingham	141	None	£1 6s.	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	Norwich Union Chambers, Congreve Street, Birmingham. W. P. Marshall and P. L. Gray	183	None	£1 1s.	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	Brighton N. H. Phil. Soc.	Museum, Church Street, Brighton. E. A. Pankhurst	185	10s.	10s.	Report, annually.
Bristol Naturalists' Society, 1862 ..	Bristol Nat. Soc. ..	S. H. Reynolds, M.A., University College, Bristol	152	5s.	10s.	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.	J. F. Tocher, F.I.C., 5, Chapel Street, Peterhead	180	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc..	B. L. Oswell, 30, High Street, Burton-on-Trent	220	None	5s.	Annual Report. Transactions, occasionally.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C...	H. E. Forrest, 37, Castle Street, Shrewsbury	190	5s.	5s.	Transactions and Record of Rare Facts, annually.
Cardiff Naturalists' Society, 1867 ..	Cardiff Nat. Soc. ..	Walter Cook, 98, St. Mary Street, Cardiff	450	None	10s. 6d.	Transactions, annually.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci...	Grosvenor Museum, Chester. G. P. Miln and W. F. J. Shepheard	868	None	5s.	Report and Proceedings, annually.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	G. A. Lewis, Albert Street, Derby ..	360	£1 1s. None	Members, 31s. 6d.; { Associates and Students, 20s.	*Transactions of Institution of Mining Engineers*, monthly.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	200	10s. 6d.	Minimum, 10s. 6d.	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc. ..	The Museum, Public Buildings, Penzance. John B. Cornish	95	None	£1 1s.	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C. ..	Public Hall, Croydon. F. J. Townend.	230	None	10s.	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C. ..	Nelson M. Richardson, Montevideo, Chickerel, Weymouth	350	None	10s.	Proceedings, annually.
Dublin Naturalists' Field Club, 1885..	Dublin N. F. C.	N. H. Alcock, M.D., and C. J. Patten, M.D., Royal Irish Academy, Dublin	180	5s.	5s.	*Irish Naturalist*, monthly. Report, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. J. Maxwell Ross, St. Ruths, Dumfries	205	2s. 6d.	5s.	Transactions and Journal of Proceedings, annually.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1900–1901.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Eastbourne Natural History Society, 1869	Eastbourne N.H. Soc.	Dr. H. Habgood, Stafford House, Upperton Road, Eastbourne	112	2s. 6d.	7s. 6d.	Transactions, annually.
East Kent Scientific and Natural History Society, 1857	E. Kent S. N. H. Soc.	H. Mead Triggs, 8, High Street, Canterbury	67	None	10s.	*South-Eastern Naturalist*, and Annual Report
Edinburgh Geological Society, '834	Edinb. Geol. Soc.	5, St. Andrew Square, Edinburgh. James Currie	260	10s. 6d.	12s. 6d.	Transactions, annually.
Essex Field Club, 1880	Essex F. C.	William Cole, 7, Knighton Villas, Buckhurst Hill, Essex	300	None	15s.	*Essex Naturalist*, quarterly; *Special Memoirs*, occasionally.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Barclay Murdoch, Capelrig, Newton-Mearns, Glasgow	210	None	10s.	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	J. J. Robertson, 207, Bath Street, Glasgow	314 Members 18 Associates	None	Members 7s. 6d. Associates 5s	Transactions and Proceedings, annually
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	Peter Bennett, 207, Bath Street, Glasgow	675	£1 1s.	£1 1s.	Proceedings, annually.
Halifax Scientific Society and Geological Field Club, 1874	Halifax S. S. G. F. C.	Literary and Philosophical Society's Rooms. F. Barker	108	None	2s. 6d.	*Halifax Naturalist*, every two months
Hampshire Field Club and Archæological Society, 1885	Hants. F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7s. 6d.	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts. N. H. Soc.	W. R. Carter, B.A., Amesbury, Watford	210	10s.	10s.	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	88	10s.	10s.	Proceedings, every two or three years.
Hull Geological Society, 1887	Hull Geol. Soc.	W. S. Parish, 1, Waltham Street, Hull	71	None	5s.	Transactions, annually.
Hull Scientific and Field Naturalists' Club, 1886	Hull Sci. F. N. C.	T. Sheppard, F.G.S., 32, Holderness Road, Hull	170	None	4s. and 2s.	Transactions, annually.
Institution of Mining Engineers	Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle upon Tyne	2,500	None	None	Transactions, monthly.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	E. G. Critchley, 29, High Street, Inverness	180	None	5s.	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	J. Pim, W. Lawson and C. H. Oldham, 35, Molesworth Street, Dublin	100	None	£1.	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Philosophical Hall, Leeds. David Forsyth, M.A., D.Sc.	70	None	5s.	Transactions, occasionally.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. & Sci. Assoc.	H. B. Wilson, Westfield, Armley, Leeds	150	None	6s.	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	Corporation Museum. Herbert Ellis	330 Members & Associates.	None	Members, £1 1s.; Associates, 10s. 6d.	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liv'pool E. Soc.	R. C. F. Annett, Royal Institution, Liverpool	502	None	Resident, £1 1s.; Non-res. and Students, 10s. 6d.	Transactions, annually.
Liverpool Geographical Society, 1891	Liv'pool Geog. Soc.	Capt. E. C. Dubois Phillips, R.N., 14, Hargreave's Buildings, Chapel Street, Liverpool	750	None	Members, £1 1s.; Associates, 10s. 6d.	Transactions and Report, annually.
Liverpool Geological Society, 1858	Liv'pool Geol. Soc	Royal Institution. H. C. Beasley	55	None	£1 1s.	Proceedings, annually.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1900–1901.—*Continued.*

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Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc...	Royal Institution. J. Maxwell McMaster	214	None	£1 1s.; Ladies, 10s. 6d.	Proceedings, annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc...	Rev. F. J. R. Young, 95, Wold Road, Norton Malton, Yorks	123	None	5s. and 2s. 6d.	Report, annually.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	158	2s. 6d.	Gentlemen, 7s. 6d. Ladies and Non-Residents, 5s.	*Yn Lioar Manninagh*, biennially.
Manchester Geographical Society, 1884	Manch. Geog. Soc. ..	Eli Sowerbutts, F.R.G.S., 16, St. Mary's Parsonage, Manchester	800	None	Members, £1 1s.; Associates, 10s. 6d.	Journal, quarterly; *Geography*, monthly
Manchester Geological Society, 1838..	Manch. Geol. Soc. ..	5, John Dalton Street, Manchester. W. Saint and J. Tonge, jun.	240	None	£1.	Transactions, monthly.
Manchester Microscopical Society, 1880	Manch. Mic. Soc. ..	E. C. Stump, 16, Herbert Street, Moss Side, Manchester	210	5s.	6s.	Transactions and Report, annually.
Manchester Statistical Society, 1833 ..	Manch. Stat. Soc. ..	63, Brown Street, Manchester. F. E. M. Beardsall and T. Gregory	210	10s. 6d.	10s. 6d.	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick ..	324	1s. 6d.	3s. and 5s.	Report, annually.
Midland Institute of Mining, Civil and Mechanical Engineers, 1869	Midland Inst Eng. .	T. W. H. Mitchell, Mining Offices, Regent Street, Barnsley	251	None	£1 10s.	*Transactions of Institution of Mining Engineers*, monthly.
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, St. Helen's Square, Norwich	250	None	5s.	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,250	None	21s. and 42s.	*Transactions of Institution of Mining Engineers*, monthly.
North Staffordshire Field Club .	N. Staff. F. C. .. .	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.; W. Wells Bladen, Stone, Staffs	456	5s.	5s.	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton N. H. Soc. ..	H. N. Dixon, M.A. 23, East Park Parade, Northampton	190	None	10s.	Journal, quarterly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of,	Northumb. N. H. Soc...	Hancock Museum, Newcastle-upon-Tyne. A. H. Dickinson and Prof. C. M. Potter	250	None	21s.	Transactions, annually.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Prof. J. W. Carr, University College, Nottingham	150	2s. 6d.	5s.	Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst. ..	J. Gardner, 3, County Place, Paisley	420	5s.	7s. 6d.	Report, annually; Meteorological Observations, occasionally.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc. ..	Museum, Public Buildings, Penzance. Dr. H. M. Montgomerie	71	None	10s. 6d.	Report, annually; Transactions, occasionally.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci. ..	Tay Street, Perth. S. T. Ellison ..	410	2s. 6d.	5s. 6d.	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, B.Sc., 105, Freehold Street, Rochdale	240	None	6s.	Transactions, biennially.
Rochester Naturalists' Club, 1878 ..	Rochester N. C.	John Hepworth, Linden House, Rochester	150	None	5s.	*Rochester Naturalist*, quarterly.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1900–1901.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Scotland, Mining Institute of, 1878 ..	Mining Inst. Scot. ..	James Barrowman, Stanecare, Hamilton, N.B.	455	None	42s. and 25s.	*Transactions of Institution of Mining Engineers*, monthly.
Somersetshire Archæological and Natural History Society, 1848	Som'setsh. A.N.H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble and Rev. F. W. Weaver	612	10s. 6d.	10s. 6d.	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc. ..	G. S. Corstorphine, South African Museum, Cape Town	132	None	£2	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	S.-E. Union .. .	George Abbott, M.R.C.S., 33, Upper Grosvenor Road, Tunbridge Wells	33 Societies	None	5s.	Transactions, annually.
South Staffordshire and East Worcestershire Institute of Mining Engineers, 1867	S. Staff. Inst. Eng. .	Alexander Smith, M. Inst. C.E., 3, Newhall Street, Birmingham	172	£1 1s. and 10s. 6d.	31s. 6d. and 21s	*Transactions of Institution of Mining Engineers*, monthly.
Toronto, Astronomical and Physical Society of, 1884	Toronto Astr. Phys. Soc.	Canadian Institute Building. Thos. Lindsay	100	None	2 dollars.	Transactions, annually.
Tyneside Geographical Society, 1887 ..	Tyneside Geog. Soc. ..	Geographical Institute, Barras Bridge, Newcastle-upon-Tyne. Herbert Shaw, B.A.	1,200	None	10s. and 5s.	Journal, half-yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C. ..	Museum, Warwick. S. S. Stanley, 3, Regent Grove, Leamington	109	2s. 6d.	5s.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C. ..	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	212	10s.	10s.	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, F.G.S., Hopton, Mirfield	168	None	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861 ..	Yorks. Nat. Union ..	W. Denison Roebuck, F.L.S., 259, Hyde Park Road, Leeds	432 and 2,41 Associates	None	10s. 6d.	Transactions, annually; *The Naturalist*, monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc. ..	Museum, York. Dr. Tempest Anderson and C. E. Elmhirst	420	None	£2	Report, annually.

INDEX OF THE MORE IMPORTANT PAPERS, AND ESPECIALLY THOSE REFERRING TO LOCAL SCIENTIFIC INVESTIGATIONS, PUBLISHED BY THE CORRESPONDING SOCIETIES DURING THE YEAR ENDING JUNE 1, 1900.*

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

SUTTON, J. R. "Do the Mining Operations affect the Climate of Kimberley?" *Trans. S. African Phil. Soc.*, vol. xi., pages 7-17, 1900.

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Section B.—CHEMISTRY.

CHAMBERS, W. H. (Midland Inst. Eng.). "Notes on Gob-Fires." *Trans. Inst. Min. Eng.*, vol. xviii., pages 154-156, 1899.

GERRARD, JOHN. "Instantaneous Outbursts of Fire-damp and Coal, Broad Oak Colliery." *Ibid.*, vol. xviii., pages 251-258, 1900.

— "An Outburst of Gas at Westleigh Colliery." *Trans. Manch. Geol. Soc.*, vol. xxvi., pages 162-165, 1899.

— "Note on an Outburst of Fire-damp at Blainscough Colliery." *Ibid*, vol. xxvi., pages 171-172, 1899.

HEDLEY, J. L., and W. LECK (N. Eng. Inst.). "Fire-damp in the Iron Ore-mines of Cumberland and Furness." *Trans. Inst. Min. Eng.*, vol. xvii., pages 284-287, 1899.

MARTIN, A. J. "The Purification of Sewage by Bacteria." *Proc. Belfast N. H. Phil. Soc.*, 1898-9, pages 32-37, 1899.

ORSMAN, W. J. "On Permitted Explosives." *Trans. Manch. Geol. Soc.*, vol. xxvi., pages 229-331, 1899.

O'SHEA, L. T. (Midland Inst. Eng.). "The Safety of Modern Mining Explosives, with Special Reference to Methods of Testing." *Trans. Inst. Min. Eng.*, vol. xvii., pages 189-209, 1899.

SPENCER, GEORGE (Midland Inst. Eng.). "The Application of Liquefied Carbonic Acid Gas to Underground Fires." *Ibid.*, vol. xvii., pages 181-183, 1899.

STODDART, F. W. "The Circulation of Nitrogen in Nature: an Account of some Indispensable Microbes." *Proc. Bristol Nat. Soc.*, vol. ix., pages 57-74, 1899.

VECQUERAY E. G. "The Nordon-Bretonneau Process of Seasoning and Preserving Timber and other Fibrous Substances by means of Electricity." *Trans. Inst. Min. Eng.*, vol. xvii., pages 427-429, 1899.

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Section C.—GEOLOGY.

BARNES, J., and W. F. HOLROYD. "On the Subterranean Excavation in Limestone Areas, and a Consideration of the Atmospherical, Physiological and Hygienic Conditions produced thereby. *Trans. Manch. Geol. Soc.*, vol. xxvi., pages 206-218, 1899.

BARRETT, W. S. "Mining Industries, etc." (Presidential Address). *Ibid.*, vol. xxvi., pages 277-282, 1899.

BARROW, GEORGE. "On the Unconformity between the Carboniferous and the Bunter, with special reference to the Cheadle Area." *Trans. N. Staff. F. C.*, vol. xxxiv., pages 98-100, 1900.

BECHER, S. J. (N. Eng. Inst.). "The Kalgoorlie Goldfield." *Trans. Inst. Min. Eng.*, vol. xviii., pages 42-49, 1899.

* The Titles of Papers on other than Mining or Mechanical Engineering, etc., have not been reprinted.

BELL, THOMAS. "Notes on the Working of Coal-mines under Sea; also under the Permian Feeder of Water, in the County Durham." *Trans. Manch. Geol. Soc.* vol. xxvi., pages 366-399, 1900.

BREWER, WM. M. "Mineral Resources of Vancouver and Adjacent Islands, British Columbia." *Trans. Inst. Min. Eng.*, vol. xvii., pages 444-451, 1899.

BURTON, F. M. "Lincolnshire Coast-Boulders." *The Naturalist* for 1899, pages 325-329, 1899; for 1900, pages 93-97, 1900.

COATES, HENRY. "Geology in relation to Art" (Annual Address). *Proc. Perths. Soc. Nat. Sci.*, vol. iii., pages 17-24, 1899.

CRANKSHAW, JOSEPH. "Coal-mining in South Russia." *Trans. Manch. Geol. Soc.*, vol. xxvi., pages 410-417, 1900

CRICK, G. C. "Note on some Fossil Cephalopoda from Cornwall." *Trans. Cornw. R. Geol. Soc.*, vol. xii., pages 338-341, 1900.

CROFTS, W. H. "Notes on the Post-Glacial Deposits of Hull and District." *Trans. Hull Geol. Soc.*, vol. iv., page 36, 1899.

CROSSFIELD, MISS M. C. "The Tremadoc Slates." *Proc. Holmesdale N. H. C.*, 1896-98, pages 11-22, 1899.

DAWSON, C. "Petroleum in Sussex." *Report Brighton N. H. Phil. Soc.*, 1898-1899, pages 10-14, 1899.

DE RANCE, C. E. (N. Eng. Inst.). "The Geology of Furness." *Trans. Inst. Min. Eng.*, vol. xvii., pages 305-313, 1899.

DICKINSON, JOSEPH. "Striated Boulder from Blackpool." *Trans. Manch. Geol. Soc.*, vol. xxvi., page 157, 1899.

DRON, ROBERT W. (Mining Inst. Scot.). "The Probable Duration of the Scottish Coal-fields." *Trans. Inst. Min. Eng.*, vol. xviii., pages 194-211, 1899.

DIXON, JAMES S. (Mining Inst. Scot.). "Notes on Hamilton Palace Colliery." *Trans. Inst. Min. Eng.*, vol. xviii., pages 55-57, 1899.

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Section I.—PHYSIOLOGY.

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Section K.—BOTANY.

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III.—INTERNATIONAL CONGRESS OF MINING AND METALLURGY, PARIS, JUNE 18TH TO 23RD, 1900.

I.—OPENING MEETING.

JUNE 18TH, 1900.

MR. HATON DE LA GOUPILLIÈRE, PRESIDENT, IN THE CHAIR.

Opening Session in the Grand Hall of the Palais des Congrès, more than 450 members being present.

At this meeting, after an inaugural address by the President, the various officers of the congress were elected, the proceedings being purely official.

The Honorary Presidents for Great Britain were:—Mr. H. C. Peake, President of The Institution of Mining Engineers; Sir William Roberts-Austen, President of the Iron and Steel Institute; and Dr. C. Le Neve Foster, H.M. Inspector of Mines.

II.—MINING SECTION.

FIRST MEETING HELD ON JUNE 19TH, 1900.

MR. HATON DE LA GOUPILLIÈRE, PRESIDENT, IN THE CHAIR, SUPPORTED BY MESSRS. CASTEL, C. LE NEVE FOSTER AND BUQUET.

USE OF EXPLOSIVES IN MINES.

Mr. DELAFOND gave a summary of the report which he had presented on the use of safety-explosives in French coal-mines.

Mr. H. LE CHATELIER presented an analysis of his report on the establishment of underground dynamite-magazines.

Mr. WATTEYNE and Mr. DENOEL analysed the report that they had presented on the explosives employed in Belgian coal-mines. They drew attention to their conclusions, especially as regards the practical utility of instituting experiments for determining the limit-charge for each kind of explosive.

Mr. KOTSOWSKY gave a summary of his report on the composition of the air of mines in the basin of the Donetz. He noted how various in different countries are the precautionary measures taken against fire-damp, and how useful it would be for mining-engineers to meet more frequently to exchange ideas on this subject.

Mr. H. Le Chatelier, in the absence of Mr. Kournakow, presented a note on the analysis of air containing fire-damp, and of fire-damp from the coal-mines of the Donetz basin.

Mr. Marsaut made some remarks upon the dangers resulting generally from the employment of explosives.

Mr. Hanarte pointed out the considerations that have led him to propose to replace the notion of the equivalent orifice of a mine by a more exact expression. He considered that the resistance to ventilation of a mine should be represented by the number of kilogrammetres (or foot-pounds) required to produce the air-current. He proposed to designate by the number 1 any mine in which a depression of one millimetre would cause the passage of one cubic metre of air. Under these conditions, the number of a mine would be represented by the expression $q/\sqrt{m}$, which, moreover, only differs by a co-efficient (0·38) from that representing the equivalent orifice.

Mr. Petit gave an analysis of the report which he had presented on the ventilation of preliminary workings in fiery mines. The first part treated of the loss of pressure due to the movement of air in passages, through regulators, or in shafts, and the second part described the methods which Mr. Petit had applied for the ventilation of preliminary workings.

Mr. Schmerber presented a communication upon the so-called "delayed explosions" attributed to explosives containing high proportions of ammonium nitrate. He concluded that numerous experiments have proved that although such delayed explosions are not inexplicable in theory, they cannot exist in practice.

Mr. Chalon noted what remedies he considered should be applied against dangers resulting from the employment of explosives in fiery mines. In addition to the dangers due to the fuze, which is easily avoided by the employment of electric blasting, others more serious were due to the explosives themselves, even to the so-called safety-explosives. By the employment of very powerful detonators, and by avoiding the presence in the cartridges of substances capable of remaining incandescent after the explosion, such dangers would certainly be diminished.

Mr. Chesneau pointed out that the experiments proposed by Messrs. Watteyne and Denoel to determine the limit-charge of various explosives did not appear to give conclusive results.

Mr. Watteyne replied in a few words to the various observations of Messrs. Marsaut, Chalon and Chesneau. He recognized that experiments made to determine the limit-charge of explosives must be interpreted with the greatest care, nevertheless they were indispensable.

Messrs. Chalon, Denoel, Kŏss and Tauzin made observations on the stemming of shots and on the employment of the very powerful charges, to which Mr. Marsaut had referred.

SECOND MEETING HELD ON JUNE 20TH, 1900.

MR. LEDOUX, VICE-PRESIDENT, IN THE CHAIR, SUPPORTED BY MESSRS. HARZÉ AND ENGEL.

MINING AT GREAT DEPTHS.

Mr. STASSART presented his report on the conditions of mining at great depths in Belgium. The limit of depth in workings is determined solely by the increase of underground temperature, and a decrease of temperature can only be obtained by the passage of powerful air-currents. The downcast and upcast shafts must therefore be of great section. In the five mines, to which Mr. Stassart referred, not more than five working districts can be worked simultaneously, taking into account the preparatory operations; and the production must be limited to 500 tons. Moderate loads must be hoisted in the shafts at a high speed, and handled very rapidly. The cable must be of aloes. Direct hoisting from a depth of 5,000 feet (1,500 metres) can only be done by means of vertical shafts. The employment of liquid air as a refrigerent may perhaps solve the question of the possibility of working at depths below 5,000 feet.

Mr. POUSSIGUE presented a report on the conditions of working at great depths, and read a supplementary note relating to the sinking and installation of a shaft 3,330 feet (1,015 metres) deep at the Ronchamp collieries.

Mr. DARPHIN read a note on the installations at the Arenberg pit of the Anzin collieries. He believed that the methods employed at the Arenberg pit could be applied in cases of mining at great depths, having regard to their very active hoisting from a depth of 2,460 feet (750 metres).

Mr. MAURICE presented a table, from which the dimensions of a cable of decreasing cross-section can simply be read off, instead of having to be calculated.

Mr. MARSAUT asked whether any one could tell him if in the manufacture o aloes-rope the same strength per unit of cross-section was obtained at the two ends of the rope.

Mr. STASSART replied that the manufacturers gave slightly different co-efficients of safety at different parts of the rope.

Mr. HARZÉ pointed out that in Belgium, on account of the thinness of the seams, the output per man was small. For each 1,000 tons the number of men to be lowered and hoisted was greater than in France. Moreover, the volume of rock to be hoisted was greater. He therefore thought that a different system would have soon to be adopted in Belgium, and especially that it will be necessary to prepare two hoisting-pits at the same time.

Prof. HENRY LOUIS was convinced that, as a matter of engineering, the question of hoisting from great depths, say above 5,000 feet (1,500 metres) would be solved. Mechanical coal-cutters and drills would take the place of hand-work, and ventilation might be obtained by means of powerful fans or liquid air. He considered that the difficulty of the problem was an economic one. It scarcely existed when work was to be continued in seams already worked, but when it was

a question of going down to unknown strata, the large and deep pits would involve the sinking of very heavy capital, which would remain unproductive for a very long time.

Mr. DESPRÈS presented a communication on the balancing of round wire-ropes. The system that he suggested allows a cylindrical drum to be employed and round ropes of decreasing cross-section.

Dr. C. LE NEVE FOSTER asked Mr. Poussigue why in sinking the Ronchamp shaft he did not use guides. He (Dr. Foster) believed, moreover, that for winding from great depths a system exhibited in the British Section presented advantages. This consisted of an arrangement by which the drum could be traversed, and was intended for a shaft in Cornwall down to a depth of 3,300 feet (1,000 metres).

Mr. J. B. MARSAUT suggested another solution, which consisted in placing a drum, 105 feet (32 metres) in diameter, between two neighbouring pits and to work it by means of gearing driven by a high-speed engine.

Mr. POUSSIGUE replied to Dr. Foster that guides were not used in sinking the Ronchamp pit, so as to save time.

Mr. TOMSON, referring to the communication of Mr. Desprès, pointed out that endless ropes at a depth of 2,000 to 2,300 feet (600 to 780 metres) vibrated to such an extent that they destroyed the shafts and themselves. They have, however, been applied in the Köpe system down to a depth of 2,300 feet (700 metres), but for greater depths that system could not be employed. For hoisting from a depth of 4,000 feet (1,200 metres), he had adopted a spiroidal drum.

THIRD MEETING HELD ON JUNE 21ST, 1900.

MR. HARZÉ, HONORARY PRESIDENT, SUPPORTED BY MR. FARBAKY.

THE EMPLOYMENT OF ELECTRICITY IN MINES.

The SECRETARY read the report of Mr. Wendelin on the employment of electricity in mines.

Mr. LIBERT analysed his report on the use of electricity in mines. He gave an account of what had been done in Belgium, and reviewed the applications of electricity to blasting, signalling and electrical transmission. He then examined the advantages resulting from the employment of electricity, and showed under what conditions the miner must choose between continuous and triphase-currents. As regards the dangers due to fire-damp, he considered that these could be reduced to a very great extent by the employment of polyphase-motors. He showed how far the question of lighting by portable electric lamps had proceeded in Belgium.

Mr. PERÈS gave an account of the installations that had been set up at the Carmaux mines. The boilers are fired by the waste-heat from the coke-

ovens, by which means the triphase-current is produced under conditions of especial economy. The current is used in part for lighting, but chiefly for motors driving fans, a winding-engine, a coke-drawing machine, and three underground pumps. He showed that the proportion of energy transmitted to the motor varied between 77 and 79 per cent. of the effective power of the driving-engine. The cost per horse-power on the former machine is only equal to 0·06d. (0·062 centime), whilst it formerly cost 0·38d. (4 centimes) with steam power.

Mr. PAUL HABETS described the electric installations at the Espérance and Bonne Fortune collieries, and considered that electric motors are preferable to steam-engines and water-pressure engines when it is a question of distributing power required intermittently at different points of the mine. He noted the precautions that have been employed, to avoid shocks dangerous to the workmen.

Mr. MAZODIER described the important electrical station that had been erected at the Grand'Combe mines. A portion of the current generated at 600 volts is directly utilized to work pumps, a fan, and a winding-engine of 125 horsepower. The balance, transformed up to 5,000 volts, is carried to a distance, and then transformed down again to 600 volts to work a pump and three fans.

REDUCTION OF MANUAL LABOUR IN MINES.

Mr. BACHELLERY gave a summary of his report on American coal-cutting machines. He indicated the development that these machines have shewn in the United States of late years and the advantages which they have produced, especially as regards increased production.

Mr. FAYOL described the machine that he had designed for cutting the very hard coal-seams of Decazeville, containing nodules of ironstone. This machine, which is still undergoing trial, has a motion resembling that of a scythe.

Mr. DOMAGE gave an account of the results obtained in the adit being driven from Fuveau to the sea, first with hand-drills, afterwards with electrically-driven rotating drills.

Mr. DE GENNES indicated the various types of coal-cutting machines in use in the United States, these machines comprising on the one part coal-cutters, on the other drills.

Dr. C. LE NEVE FOSTER criticized the phrase "pick coal-cutter," which has been adopted for percussion-machines.

Mr. BORNET gave an account of the improvements which he had made of recent years in the drills constructed by him. He indicated the results that have been obtained by a continuous injection of water, and described two new types of electric drills, one rotative and the other percussive.

FOURTH MEETING HELD ON JUNE 22ND, 1900.

MR. PELLATI, PRESIDENT, IN THE CHAIR, SUPPORTED BY DR. C. LE NEVE FOSTER, AND MR. HENRI FAYOL.

THE EMPLOYMENT OF ELECTRICITY IN MINES.

Mr. DUVIVIER presented a communication on large electric winding-engines. He compared the working costs of a steam-engine and an electric-engine of 400 horsepower. He considered that the latter will induce an economy of £13 15s. (344 francs) per day, and allowing that the amortization of the cost of construction of the central electrical station amounted to £800 (20,000 francs) *per annum*, there would be a saving of £3,200 (80,000 francs).

Mr. BRESSON gave an account of the electric installation at the Nœux mines.

Mr. SMITS read his report on the Wetherill process, which utilizes the feeble magnetic power of minerals which up to late years had been considered as non- or feebly magnetic. He described the process as it had been applied at Franklin, Broken Hill and Löhmannsfeld.

Mr. PELLATI drew attention to the improvements in the mining industry in Sardinia. These improvements are in great part due to advances in the dressing of minerals. They have permitted the same production to be maintained, although treating a poorer raw material, and a larger quantity.

Mr. DE CASTELIN presented a communication on the magnetic separator employed at the mines of Mechernich, and pointed out the advantages of this system.

Mr. BUISSON presented a note on the dressing of coal, including tipplers, screens, belts, and picking and loading appliances.

Prof. HENRY LOUIS, in discussing the question of magnetic separation, referred to the system of allowing mineral to fall down a tower 100 feet (30 metres) high, in which electro-magnets are so disposed as to draw the magnetic portions to one side. Separation is thus performed without any moving parts, and quantities up to 300 tons an hour can be treated.

FIFTH MEETING HELD ON JUNE 23RD, 1900.

MR. KOTSOWSKY IN THE CHAIR, SUPPORTED BY MR. DE CASTELNAU.

MISCELLANEOUS QUESTIONS.

Mr. PELLATI gave an analysis of the report which he had presented to the Congress on the employment of helicoidal wire for cutting marble in the Carrara quarries.

Mr. BERTOLIO called attention to the possibility of employing helicoidal wires for driving tunnels.

Mr. SZYMANOWSKI gave a summary of his report upon the mining industry in the neighbourhood of Krivoï-Rog. He called special attention to the colossal resources of coal and iron-ore that exist in that region and in the basin of the Donetz.

Mr. HABETS gave an account of the work done by the Société de l'Industrie houillère de la Russie méridionale, often known as the Société de Gorlowka.

Mr. DOUGLAS, in the absence of Mr. Rothwell, presented statistics showing the rapidity of the development of the mineral industry in the United States. At the present moment, that country alone produces one-third of the coal of the world, one-third of the pig-iron, and a still greater proportion of the steel.

Mr. JESSÉ-ROUX presented a memoir on the manufacture of briquettes by means of naphtha-residues.

Dr. C. LE NEVE FOSTER pointed out the utility of international mineral statistics. He considered it very desirable that the various Governments should agree upon a uniform basis for their statistics, especially in what concerns the production of mines and quarries, the number of persons employed, the value of their productions, and the fatal accidents.

Messrs. HARZÉ, HENRY LOUIS, PELLATI, and DUJARDIN-BEAUMETZ spoke on the same subject.

Mr. PETITJEAN referred to the appliances at the Albi mines for compressing the coal in retort-ovens, in order to increase the density of the coke.

Mr. PŒCH gave an account of the present state of development of the mineral and metallurgical industry of Bosnia and Herzegovina.

Mr. HABETS read a communication on miner's ankylostomasia.

III.—METALLURGICAL SECTION.

FIRST MEETING HELD ON JUNE 19TH, 1900.

SIR WILLIAM ROBERTS-AUSTEN IN THE CHAIR, SUPPORTED BY MR. DE WENDEL.

DIRECT UTILIZATION OF BLAST-FURNACE GASES.

Mr. HUBERT presented his report on this subject.

Mr. GREINER pointed out the importance of limiting to the utmost the consumption of coal.

Mr. DEMENGE spoke of the two-cycle motors constructed by Mr. Œchelhäuser.

Mr. DUTREUX gave an account of a Kœrting motor working in a double cycle, upon both faces of the piston, that is to say, like a steam-engine.

SECOND MEETING HELD ON JUNE 20TH, 1900.

PROF. TSCHERNOFF IN THE CHAIR, SUPPORTED BY MESSRS. TAUZIN AND SCHNEIDER.

DIRECT UTILIZATION OF GASES FOR POWER-PRODUCTION.

Mr. REUMAUX presented a communication on the employment of coke-oven gases in explosion-motors.

METALLURGY OF IRON AND STEEL.

Mr. BRESSON gave an account of his study of the manufacture of Bessemer basic steel.

Mr. TISSOT read a paper on the present condition of the manufacture of steel-castings.

Prof. HOWE read a paper on the progress in the manufacture of steel in the Martin furnace. He pointed out the reasons of the rapidity of the operations in the Bertrand-Thiel process, and then pointed out the advantages of the Talbot or continuous process on a basic hearth, and suggested that it might be possible to combine the two processes. Finally, he referred to the duplex process, which consisted in combining the Bessemer and Martin processes.

Messrs. TAUZIN, ESCALLE, BRESSON and LODIN continued the discussion.

Mr. BABU presented his report on the manufacture and working of special steels.

Mr. DUMAS gave some supplementary information on the question of the allotropism of iron in nickel-steels.

Mr. LE CHATELIER spoke on the subject of nickel-steels.

THIRD MEETING HELD ON JUNE 21ST, 1900.

PROF. HOWE IN THE CHAIR.

METALLURGY OF IRON AND STEEL.

Mr. PRALON treated the question of hardening and tempering steel.

Mr. LE CHATELIER pointed out the disproportion between the amount of work done upon the special steels and the results obtained. He suggested that an international committee might be founded, to indicate the studies to be pursued and the order of these researches.

The PRESIDENT stated that a committee of this kind had already been formed in the United States.

Mr. HUTH gave an account of casting by the employment of centrifugal force.

Prof. TSCHERNOFF spoke on the subject treated of by Mr. Le Chatelier.

The PRESIDENT pointed out that his countrymen were studying the allotropic modification of metals.

Prof. TSCHERNOFF gave an account of the action of magnetism upon liquid metal.

FOURTH MEETING HELD ON JUNE 22ND, 1900.

MR. DOUGLAS IN THE CHAIR, SUPPORTED BY MESSRS. CARNOT AND ROLLAND.

MISCELLANEOUS QUESTIONS.

The PRESIDENT, who is engaged in copper-smelting in the United States, begged to point out that whilst his country was producing at the present moment three to four million pounds of that metal, or almost half the world's consumption, this was due to the employment of a French process, namely the Manhes process.

The SECRETARY read Mr. Héroult's paper upon aluminium and its products, obtained by means of electricity.

Mr. MAUSSIER gave an historical account of a series of experiments made by him from 1872 up to 1890, with the object of utilizing forge sinters, after having removed the silicon from them, and afterwards upon the production of aluminium by the simple reduction of clay from which the silicon had been first removed. The results were encouraging, but not decisive.

Mr. LODIN believed in the possibility of the reduction of aluminium by carbon, but only at a temperature exceeding 3,600° Fahr. (2,000° Cent.), which had only been obtained hitherto in the electric furnace.

Mr. JANNETAZ spoke upon electrolysis as applied to copper, and upon the David selector, by means of which, in the course of Bessemerizing copper, the minor metals, together with nearly all the gold and silver present, can be removed.

The PRESIDENT stated that he had had experience in America of the David selector, but it appeared to him that its use did not present any real economy, seeing that the cost of electrolysis had been lowered to 4d. (8 cents) per pound of matte.

Mr. DAVID gave an account of the advantages of the apparatus that he had invented.

Mr. LODIN pointed out that blowing from the bottom with a great pressure in Bessemerizing copper was an approximation to what Bessemer himself had done as regarded steel.

The PRESIDENT preferred the horizontal tuyeres of the Manhes converter.

Mr. CLERC read a note upon alumino-thermic metallurgy, invented by Dr. Goldschmidt.

Mr. HOWE claimed for his countrymen, Messrs. Greene and Wahl, of Philadelphia, the honour of having in 1892 by this method obtained pure metals, manganese, chromium, etc.

FIFTH MEETING HELD ON JUNE 23RD, 1900.

PROF. TSCHERNOFF IN THE CHAIR, SUPPORTED BY MR. HATON DE LA GOUPILLIÈRE.

MISCELLANEOUS QUESTIONS.

Commander HARTMANN gave a summary of his paper on the phenomena that accompany the permanent deformation of metals.

Messrs. HATON DE LA GOUPILLIÈRE and GROBOT spoke on this subject.

Mr. BOUSQUET gave a very brief summary of his memoir on the cyanidation of auriferous minerals in the Transvaal.

Mr. LEVAT said a few words on the working of auriferous alluvials, by means of dredgers.

IV.—FINAL MEETING, JUNE 23RD, 1900.

MR. HATON DE LA GOUPILLIÈRE, PRESIDENT, IN THE CHAIR.

A desire was expressed that another similar congress should be held at Liége in 1903, and at St. Petersburg in 1906.

The complete proceedings of the Congress are published by the Société de l'Industrie Minérale, Saint-Étienne, Loire, France.

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EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.

M.—Midland Institute of Mining, Civil and Mechanical Engineers.

S.—Mining Institute of Scotland.

N.E.—North of England Institute of Mining and Mechanical Engineers.

N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.

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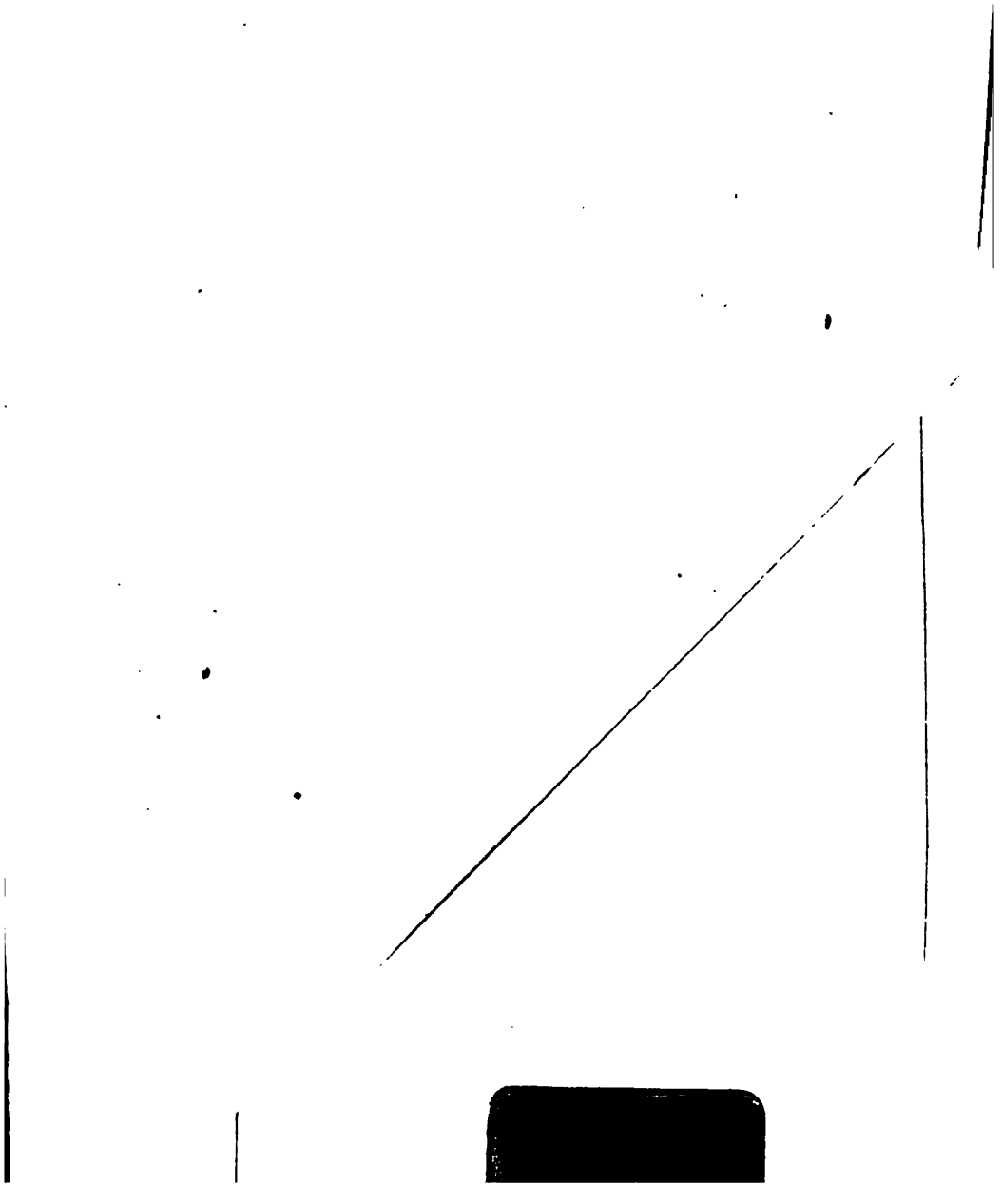
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